Evaluation of the Navy's Sea/Shore Flow Policy

Hoda Parvin , Karan A. Schriver, Greggory J. Schell, Maryann N. Shane

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Henry S. Griffis

Henry S. Griffis, Director
Defense Workforce Analyses Team
Resource Analysis Division

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Abstract

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Our key insights in this study follow. A single policy should not be applied to all communities because they are very different. Therefore, increasing the length of sea tours may not affect sea manning much for some communities. Navy manning is a result of complex interactions among factors, making variability inevitable. Policy improvement can lead to a more steady manning level, but the variability remains, even if the system is optimized. In building a Discrete-Event Simulation model, we discovered key factors that should be included in the Navy's Sea/Shore Flow Model, such as initial assignment of sea versus shore, advancement, and short-term versus long-term impact of policy change.

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Executive Summary

Navy manning, specifically fleet manning, is an important focus for Navy leadership. The Navy has set minimum at-sea manning levels to maintain required readiness. To assist in achieving these sea manning levels, the Navy uses a sea duty assignment policy. The sea duty assignment policy has changed substantially over time, most notably in August 2008, with the introduction of the Sea/Shore Flow Model (SSFM), which allowed the Navy to shift from a Sea/Shore Rotation (SSR) policy to a Sea/Shore Flow (SSF) policy.

SSF attempts to optimize enlisted career paths and provide optimal sea tour lengths through the use of an optimization model. The SSFM establishes prescribed sea tours (PSTs) for each enlisted community. Periodically, the Navy changes the PST for individual communities to account for billet structure adjustments and inventory changes. Since its introduction, SSF PSTs have been changed three times: in July 2011, in December 2012, and in September 2015.

The impact of increased PST on manning at sea is not a trivial relationship to investigate. The Navy currently uses the SSFM to estimate this impact, but it has some limitations. For instance, it is a deterministic, steady-state model. In FY 2014, CNA developed a Discrete-Event Simulation model to evaluate the impact of sea/shore flow policy (the DES-SSF model) and compared the results with the SSFM for one enlisted community. We found an apparent gap between the predictions from the SSFM and the predictions from the DES-SSF. The goal of this study was to evaluate the Navy's SSFM and propose practical ways to enhance its performance. To do so, we enhanced DES-SSF with such factors as advancement and various processes related to manpower to test the validity of the SSFM. We tested the accuracy of the model on nine communities, focusing on those that have had a change of policy with increased PSTs in 2011. Other selection criteria for our test communities included mission area representation, Professional Apprentice Career Track (PACT) sailor quotas, female accession percentage, sea centricity, and enlisted program (contract length). We also included a community with high first-tour shore rotation of sailors. It was determined that these criteria would provide the best cross-representation of the enlisted force while allowing us to test the SSF policy against current Navy programs and initiatives.

We then collected Navy data on key inputs of the model, including continuation rates, advancement, average length of initial training, and PSTs. Our overall findings

suggest that the SSFM works as advertised, but, in some cases, it overestimates the impact of PST change on sea manning when compared with the results from the CNA DES-SSF.

We found that manning at sea and shore are complicated matrices that result from several changing factors, such as inventory shortfalls, attrition, advancement, and limited duty (LimDu). As such, manning variation will exist at some level, no matter what policy is implemented or how perfectly it is optimized. Nevertheless, this natural variation can be bounded and controlled through policy improvement in the long term. It is much harder to understand and quantify the short-term impact of any change, but it is necessary to understand its importance because it can take a relatively long time for a system to achieve the steady state.

In our efforts to enhance the DES-SSF, we found that the following are key factors in improving the performance of sea/shore flow modeling and the validity of the results of such modeling:

- **Sea versus shore initial assignment:** Including the feature of assigning sailors to sea versus shore would change the SSFM's performance. In reality, change in sea tour length will not be as effective when not all sailors are subject to the new policy. We recommend the addition of a feature to the SSFM involving the assignment of a percentage of sailors to shore immediately following training.

- **Advancement:** The current SSFM does not model advancement and its complex effect on manning. The billets that are input to both the SSFM and the DES-SSF are categorized by paygrade, so it would be beneficial for advancement to be added to all its features, such as high-year tenure and minimum time in grade. Doing so will enable the model to return a more realistic outcome.

- **Short-term versus long-term impact of PST change:** The SSFM is a steady-state model; it does not provide any insight on the change in manning between the time of the policy change and achievement of the steady state. It also does not give any information about how long it takes to achieve steady state. Is it three years after policy change? Is it ten years later? Our findings confirm that the time and the pattern of the achievement of the steady state are different for the various enlisted communities.

- **Alternative policies:** In some cases, a less disruptive increase in sea tour lengths can be made by increasing the percentage of personnel who are sent to longer sea tours or shorter shore tours rather than by increasing PST length for all sailors in a given community. The Navy has a policy in place to do this under its plus six (sea) minus six (shore) projected rotation date adjustment authority and the early return-to-sea policy, which allows sailors

to be returned to sea duty after 24 months at shore. This particular policy might not entirely alleviate the conflict between Navy manning goals and equitable rotation patterns for all communities. However, including alternative policies makes SSFM more helpful in improving sea manning. SSFM can further include this alternative policy in capturing the impact of those selected through the use of sea duty incentive pay.

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Glossary

ALNAV	All Navy
ASVAB	Armed Services Vocational Aptitude Battery
AVF	All-Volunteer Force
BCR	Billet Change Request
DES	Discrete-Event Simulation
DES-SSF	Discrete-Event Simulation-Sea/Shore Flow Model
EMC	Enlisted Management Community
EMR	Enlisted Master Record
EPA	Enlisted Program Authorization
FAC-G	General Duty Shore Billets
FFC	Fleet Forces Command
IA	Individuals Account
LimDu	Limited Duty
LOS	Length of Service
PACFLT	Pacific Fleet
PACT	Professional Apprenticeship Career Track
POM	Program Objective Memorandum
PMO	Production Management Office
PRD	Projected Rotation Date
PST	Prescribed Sea Tour
RPM	Rating Phasing Matrix
SDIP	Sea Duty Incentive Pay
SME	Subject Matter Expert
SSF	Sea/Shore Flow
SSFM	Sea/Shore Flow Model
SSR	Sea/Shore Rotation
STF	Street to Fleet
TFMMS	Total Force Manpower Management System
TPPH	Transients, Prisoners, Patients, and Holdees
YOS	Years of Service

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Introduction

Navy manning, specifically fleet manning, is a key focus for Navy leadership. As such, the Navy has set minimum at-sea manning levels to maintain required readiness for afloat units. Since FY 2008, however, the Navy has been undermanned at sea to varying degrees.

To improve at-sea manning levels, the Navy has developed and implemented a number of sea duty manning policies. The key policy designed to affect the Navy's sea duty manning is the sea duty assignment policy, which has changed substantially over time, most notably in August 2008, with the introduction of the Sea/Shore Flow Model (SSFM). The SSFM allowed the Navy to shift from a Sea/Shore Rotation (SSR) policy to a Sea/Shore Flow (SSF) policy.

SSF attempts to optimize enlisted career paths and provide optimal sea tour lengths through the use of an optimization model. The SSFM establishes prescribed sea tours (PSTs) for each enlisted community. Periodically, the Navy changes the PST for individual communities to account for billet structure adjustments and inventory changes. SSF PSTs have changed three times since they were introduced: in 2011, in 2012, and in 2015. When PSTs were changed at one of these dates, not every community experienced a change. For example, the 2015 change applied only to the communities of nuclear trained sailors.

Understanding the effects of increased PST on manning at sea is not trivial. The Navy currently uses the SSFM to estimate this impact, although the SSFM is a deterministic, steady-state model. In FY 2014, CNA developed a Discrete-Event Simulation model to evaluate the impact of sea shore flow (the DES-SSF model) and compared the results with SSFM for one enlisted community. We found an apparent gap between the predictions from the SSFM and those from the DES-SSF. The FY 2014 study by CNA recommended a follow-on analysis to examine additional communities over a longer period of time to test whether the study's findings generally hold true.

In this study, we explored the following enhancements to our simulation model:

- Analyze historical data on shore tour length to test the validity of the current simulation assumption that shore tour lengths of sailors equal their prescribed shore tour lengths.

- Track simulated sea inventory by length of service, allowing us to examine the effect of SSF PST changes on the experience profile of sailors at sea.

- Add advancement to the simulation model and track the effects of SSF PST changes on sea manning rates by paygrade.

Along with applying the simulation model to more enlisted management communities (EMCs) and for a longer time period, these suggested simulation model enhancements should improve the precision of the model.

Background

The Navy is a sea-going service. Inherent in its mission is the requirement to patrol and protect the seas. To accomplish this mission, ships must deploy, and crew members must be prepared to go to sea. Under conscription, the Navy was able to maintain its at-sea manning without much thought to the impact of lengthy sea tours on sailor quality of life. However, as the nation moved to an all-volunteer force (AVF), the Navy recognized its need to move away from its sea tour policy in which sailors remained at sea indefinitely, rolling ashore based on time in grade and shore billet availability. Accordingly, the Navy's SSR policy was established in 1974 in response to the establishment of an AVF. SSR provided predictable sea tour lengths necessary for the Navy to recruit and retain sailors to support the AVF. Under SSR, sea tour lengths of sailors were determined by a ratio of sea billets to shore billets for each rating and paygrade. SSR set fixed projected rotation dates (PRDs), which were used to project inventory.

Due to fiscal pressures and better technologies in recent years, the Navy has reduced its shore billets and has increased the need for fewer but more experienced sailors at sea. This has resulted in significant changes to the ratios of sea versus shore billets and has increased sea centricity for many enlisted communities. At the same time, Navy afloat platforms have become progressively more complex, requiring the Navy to grow and maintain a more senior career force of highly technical individuals. The demand for more senior trained personnel has forced the Navy to develop a better policy and system to ensure proper manning of its operational units while providing a more desirable work-life balance throughout a sailor's career by working to offset the often arduous nature of sea duty with predictable periods of meaningful work ashore [1]. The Navy understands that its sea tour policy can affect both quality of life and reenlistment decisions. As a result, in 2008, the Navy introduced a move away from its Sea/Shore Rotation policy to Sea/Shore Flow (SSF). SSF was developed and implemented to improve the Navy's ability to balance competing considerations of sea/shore distribution, retention, and morale by attempting to provide an optimal balance between sea and shore duty.

How Community Work Requirements Affect SSF

In this section, we look at how enlisted community work requirements affect SSF PSTs. A challenging question faced by the Navy is the number of shore billets necessary to support desired sea manning levels. In planning for new ships or squadrons, the Navy must ensure that the number of shore billets available for rotation is consistent with increased (or decreased) sea billet requirements. This is not an aggregated issue; the Navy must manage these billet ratios for each of its 100-plus enlisted management communities.

Each of the Navy's enlisted communities has different sea and shore requirements. Some communities have a preponderance of billets at sea and very few ashore, while others have the majority of their billets ashore. These differences are reflected by differing PST lengths produced through the SSFM.

Under SSF, the Navy looks at the compounded sea time that a sailor is expected to serve at sea based on his or her enlisted community's ratio of sea and shore billets. As a result, the enlisted communities (ratings) have been classified into the following SSF categories:[1]

- Sea-intensive (17 ratings): ratings for which SSF career paths have been set to the maximum sea tour lengths allowed by policy, resulting in 216 months, or 18 years, at sea over a 30-year time horizon: ABE, ABF, ABH, AO, ENSW, GSE, GSM, DC, EMSW, ICSW, FC, FCAEGIS, BM, QMSW, EOD, SO, and SB.

- Sea-centric (30 ratings): ratings for which SSF career paths result in at least 180 months (15 years) but fewer than 216 months (18 years) at sea over a 30-year time horizon: AM, AE, AT, AW, MMSW, HT, GM, STG, OS, CS, SH, LCAC, LS, ETSNV, FT, MMSS, MMSSW, CSSS, STS, EMNUCSS, EMNUCSW, ETNUCSS, ETNUCSW, MMNUCSS, MMNUCSW, ELTNUCSS, ELTNUCSW, CM, EO, and SW.

[1] SEAL (SO) and SWCC (SB) follow special career paths and remain operational for over 10 years. Nuclear-power-trained ratings follow career paths as designated by Naval Reactors.

- Shore-centric (29 ratings): ratings for which SSF career paths result in fewer than 180 months (15 years) at sea over a 30-year time horizon: AD, AME, AG, AS, AZ, PR, MR, ETSW, IT, CTM, CTT, IS, MC, LN, MA, NC, PS, RP, YN, MN, MT, LSSS, YNSS, ITS, ND, BU, CE, EA, and UT.

- Shore-intensive (7 ratings): ratings that do not have career paths defined by SSF: AC, CTI, CTN, CTR, MU, NCCR, and HM.

Navy policy requires sailors to spend no more than five years at sea and no less than two years on shore per tour. These ceilings and floors are implemented regardless of the sea/shore billet ratio for a given community. Yet, sea billets to support this rotation are insufficient for some communities. SSF is not defined for these shore-intensive communities, meaning the Navy does not require them to comply with the SSF policy.

At the other end of the spectrum, this is not the case for sea-intensive communities. Sea-intensive communities do not have enough shore billets to balance the sea requirements. In an attempt to improve this imbalance, the Navy assigns generic shore duty billets, known as FAC-G billets, proportionally across these communities. FAC-G billets include many of the special duty assignments, such as recruiter, company commander, and staff. Even with these additional shore duty billets, many of these sea-intensive ratings continue to be unbalanced, having too many sea duty billets relative to shore billets. For these communities, the SSFM indicates that the PSTs should be greater than the 60-month ceiling set in the Navy's policy. There is no SSF exception for sea-intensive communities; they must adhere to the policy ceiling of 60 months. This mismatch results in a sea manning gap for these communities.

Other Navy manning policies should also be considered. Minimum shore tour lengths of 36 months (or greater) must be met for such tours as recruiters, instructors, company commanders, and other special duty assignments. Under SSF, most shore tours are 36 months in length. Recent changes in the policy allow greater latitude for the distribution system to pull sailors from shore after meeting the 24-month minimum, with the exception of sailors serving in these special duty assignments. Because the sea-intensive communities use these types of assignments to improve sea/shore imbalances in the policies, restricting the ability to truncate these shore tours at 24 months can exacerbate the manning gaps.

In addition, a number of communities rotate sailors to shore tours first or have a percentage of sailors who serve shore tours first. These communities often have shorter initial shore duty and are not represented in the SSFM accurately because the model assumes sea duty as the initial tour.

The preceding examples represent only few of the numerous variations that may occur to PST lengths for a given community. These circumstances need to be explicitly considered in any model that is used in planning sea/shore flow.

Since the introduction of SSF, there have been three revisions that have resulted in changes to PSTs for some enlisted communities. Revisions were released in 2011, 2012, and 2015 to adjust PSTs in response to community changes in billets, continuation rates, and inventory.[2] The 2011 revision also included the addition of T+X communities, which were created to extend initial enlistment contract length for sailors in communities with longer training pipelines. Increasing total contract time meant the Navy would realize more months at sea after training was completed. Also included in T+X were communities that do not have long training pipelines but are considered sea-centric (i.e., BM and ABH). For these communities, attempts were made by the Navy to match necessary initial sea tour PST returns to service contract length.

The Navy believed the SSFM approach would alleviate one of SSR's biggest issues: the ratios of sea shore billets by paygrade did not always align with the paygrades that sailors held as they flowed between sea and shore billets throughout their careers [2]. Under SSF, sea tour lengths are determined by experience level (sea tours completed) rather than by paygrade of sailors in each EMC. We found in our analysis that this remains an issue because SSF does not correct this mismatch for all communities. The PSTs determined by the SSFM do not always return sufficient sailors at the requisite paygrade to fill the paygrade distribution of billets.

The SSF is an improvement over past policies; however, it must take into account several other factors in order to realize an optimal balance between sea and shore duty. In this study, we included many of these factors, such as advancement, and tested our model on several communities. We also assessed the impact of policy change in the initial years following the change but before reaching the steady state. Giving the Navy the ability to capture the short-term and long-term behavior of the system is one of the main contributions of this study.

[2] The Navy announced revisions to enlisted community PST lengths in Navy administrative messages (NAVADMINs) released in 2008 (NAVADMIN 234/08), 2011 (NAVADMIN 201/11), 2012 (NAVADMIN 361/12), and 2015 (NAVADMIN 285/15).

Evaluating the SSFM

In this section, we look at the Sea Shore Flow Model developed by the Navy. We study the model parameters and seek to identify potential gaps and areas for improvement.

Introduction

SSFM is an informative, Excel-based tool for illustrating how changes to sea and shore tour lengths affect the billet fill rates at sea and at shore. The SSFM is a user-friendly tool with graphical outputs of key measures that are important to decision-makers. It allows for a robust test of various tour lengths; however, we find that the optimization implemented in the SSFM can be significantly improved by using a heuristic search algorithm that is available within Excel.

SSFM methodology

The SSFM is a deterministic flow model of Navy sailors from initial training through their last shore duty. Although stochastic elements are included (e.g., continuation rates), the model uses expectation rather than random number generation to incorporate those stochastic features.

To use the SSFM, the user interacts with the first sheet of the Excel file. First, the user selects a rating and a fiscal year (e.g., AM in FY18). For the selection, the Excel file populates the length of the initial individuals account (IA), the four sea tours, the four shore tours, and the time between shore and sea tours (additional time for leave, transit, and training) from the archived solution. The Excel file also shows the continuation and friction[3] (pregnancy, LimDu, etc.) rates by length of service (LOS).

[3] Friction is caused by inefficiency in the personnel management system due to four key factors: sailors not distributable due to limited duty (LimDu) or pregnancy; distribution inefficiencies, such as Individual Augmentee; SSF imbalance, turnovers, advancements, double stuffs, and billet churn; and inventory mismatch of strength to authorization.

Combining the continuation and friction rates with the period lengths, the SSFM computes the total number of billets that will be expected to be filled at sea and at shore.

Recruits are sent first to a student billet, which is a billet funded in the IA. Next, all sailors who did not attrite or who were not lost to friction by the end of the initial IA continue to their first sea tour. Further attrition and friction are then applied to compute the number of sailors who make it to the first shore tour. This process repeats through 30 years of service, where the duration of the fourth (final) shore tour is forced to be 360 months less the sum of the lengths of all prior periods.

The sum of the number of sailors across the four sea tours is set as the Model (M) estimate of sea tours. Similarly, the sum across the four shore tours plus initial IA is set as the model estimate of shore tours. The Model estimates are then subtracted from the selected fiscal year enlisted program authorization (EPA) Billet (B) count to compute the difference, Delta (B-M). The user may then adjust the length of IA, sea tours, shore tours, and time between tours to determine how those adjustments affect Delta.

Other metrics computed by the SSFM include the experience level (in years of service) of the average sailor at sea, the fill rate for each sea tour, and the number of E5 billets filled by sailors on their first sea tour. Although the SSFM shows the breakdown of the EPA billets by paygrade and sea or shore tour for the stated FY, the model does not explicitly track the promotion of sailors, given the sea and shore tour lengths. Therefore, the model cannot compute the percentage of billets for a particular paygrade filled by sailors with that paygrade (e.g., number of E6 sea tour billets filled by E6 sailors).

SSFM optimization approach

The SSFM contains an "Optimize" option to help the user determine optimal period lengths. The user may choose from two objective functions to optimize: "Maximize Sea Shore Flow Fit" or "Minimize Tour Length Changes."

For the option to Maximize Sea Shore Flow Fit, the SSFM seeks a combination of period lengths that would minimize a function of the overmanning/undermanning of the sea tours. The objective function is not the Delta shown to the user, but rather a complex function relating the number of billets in each sea tour to the length of the tour, and a ratio of the number of sailors in each sea tour to the number of billets for particular paygrades (e.g., E5 and E6 for the 2nd sea tour), plus a penalty (weighted separately by overmanning/undermanning) for an imperfect sea fill rate. The function does not appear to have an easily comprehensible interpretation and does not appear to depend on the fill rate for shore tours.

For the option to Minimize Tour Length Changes, the objective function is to minimize the sum of deviations of sea tour lengths (proposed sea tour lengths less the NAVADMIN sea tour lengths), plus a penalty (weighted separately by overmanning/undermanning) for an imperfect sea fill rate. This objective function is more readily understood but does not appear to depend on the deviations from NAVADMIN for shore tours.

Both optimization problems are solved using the same method: a two-stage, exhaustive search of tour lengths. This brute force method iterates through combinations of shore and sea tour lengths to find the combination that minimizes the objective function.

First, the exhaustive search iterates through all combinations of the first, second, and third shore tours. The length of the fourth sea tour is adjusted to ensure that the fourth shore tour is never less than 0 month. The iterations consider six-month increments between 30 and 60 months for each shore tour length. From all the shore tour combinations, the best combination (i.e., the combination that minimized the objective function) is saved. For the best combination of shore tour lengths, the exhaustive search next iterates through combinations of the four sea tour lengths, ensuring that the fourth sea tour is never less than 0 month. From these combinations, the sea tour combination that minimizes the objective function is reported as the optimal solution.

The benefit of using the two-stage, exhaustive search is the relatively short solution time for small problems and the ease of explanation and implementation. However, this exhaustive search approach suffers from long solution times if the model allows one-month intervals, rather than six-month intervals, for the sea and shore tour lengths. The exhaustive search is also a procedure that does not use learned information (e.g., features of previously considered solutions that yield improved objective function values) to minimize the objective function. Another drawback of this approach is the segregation of the shore and sea tour length determinations by the implementation of the exhaustive search in order to reduce the search space. This restriction prevents the solution from considering all combinations and may produce suboptimal solutions.

Alternative: Evolutionary algorithm

As an alternative approach, we used the evolutionary algorithm from Excel's solver add-on to determine the optimal sea and shore tour lengths. Evolutionary algorithms are heuristic search algorithms in which the search for better solutions is based on the genetic process observed in nature. In nature, we observe natural selection, reproduction, and random mutation. These processes are replicated in Excel's evolutionary algorithm by coding a computer analog of the processes.

Natural selection in the animal kingdom is the survival of animals that possess features that make them thrive in their environment. In the evolutionary algorithm, natural selection is coded by keeping solutions that have good objective function values. These good solutions are then available to inform the search for better solutions. In the case of the option to Maximize Sea Shore Flow Fit, an ideal objective function value is small (as we are interested in minimizing the function). Natural selection also implies the death of animals with unfavorable features. In the evolutionary algorithm, some solutions that yield poor objective function values are removed. The removal of these poor solutions prevents them from affecting the search for better solutions. Equating to the concept of natural selection, death prevents them from reproducing and passing along bad genes.

Next, reproduction is observed in the animal kingdom when two animals produce an offspring that shares features of both parents. This mixing of the parents' features may yield better or worse survivability for the offspring. In the evolutionary algorithm, breeding is performed by randomly selecting features from two or more solutions to generate a new solution. If the parents of the new solution are good solutions, the offspring is also likely to be a good solution, or even a better solution.

Finally, random mutation in the animal kingdom is observed when genetic anomalies produce features that make the animal different from its peers. These genetic anomalies may either improve the survivability of the animal or reduce its fitness. In the evolutionary algorithm, random mutation is implemented by randomly changing parts of the solution. For example, a random mutation of a solution that sets all sea tour lengths to 36 months would be to change the first sea tour length to 42 months and the last sea tour length to 30 months. This random mutation may lead to a better objective function value (i.e., a lower value) or a worse value.

The process of selection, reproduction, and mutation in the evolutionary algorithm is implemented iteratively to search the solution space for better solutions. Overall, by comparing this search to the two-stage exhaustive search, we can conclude that the evolutionary algorithm makes intelligent use of the information provided by the solutions to more quickly and efficiently identify the best observed solution.

Other benefits of the evolutionary algorithm include the ability to search over a refined solution space, the ability to jointly determine shore and sea tour lengths, and control of key algorithm parameters. The intelligent search enables a more efficient search of the solution space (i.e., all feasible combinations of shore and sea tour lengths). The more efficient search allows the model to consider shore and sea tour lengths that are multiples of one month (e.g., 30-, 31-, 32-month tour lengths), as opposed to the six-month multiples in the exhaustive search (e.g., 30-, 36-, 42-month tour lengths). With one-month multiples, the evolutionary algorithm has more control and freedom to minimize the objective function. For the exhaustive search, considering all combinations of one-month multiples of shore and sea tour lengths would require too much computation time. Similarly, the exhaustive search could not

consider sea and shore tour lengths jointly; rather, it searches over shore tour lengths and then searches over sea tours. With the intelligent and efficient search capability of the evolutionary algorithm, we are able to search over shore and sea tour lengths simultaneously. By doing so, we are able to find better solutions than searching over shore and sea tours sequentially.

The algorithm also contains adjustable parameters that offer the user the ability to change the solution speed and quality of the solution. These parameters include convergence (i.e., a threshold for stopping the search for better solutions) and the mutation rate (i.e., the percentage of solutions that will be changed to explore the solution space). The algorithm and the adjustable parameters are implemented via a graphical user interface in Excel, which requires no additional coding or knowledge of Visual Basic.

We compared the performance of the two-stage, exhaustive search approach to the evolutionary algorithm for a set of ratings in FY 2021.

Table 1 provides the important outcomes. The Objective column is the value of the objective function for Maximize Sea Shore Flow Fit. The Delta columns are the differences in the number of billets according to the EPA and the number of billets filled by the Model. The Run Speed is the time (in seconds) it took Excel to find the "optimal" solution for each method.

Table 1. Comparing the results of two-stage exhaustive search and evolutionary algorithm in SSFM

	Two-stage exhaustive search				Evolutionary algorithm			
EMC	**Ob-jective**	**Delta for Sea**	**Delta for Shore + IA**	**Run Speed**	**Ob-jective**	**Delta for Sea**	**Delta for Shore + IA**	**Run Speed**
EOD	525%	-1	5	45	378%	0	6	10
AE (A200)	127%	-4	107	61	89%	0	103	33
STG (B340)	291%	-7	152	78	250%	0	144	29
QM (B450)	550%	5	120	47	7%	0	125	61
ITS (C260)	6305%	24	-11	99	604%	1	11	46
BU (H100)	120%	0	60	113	88%	0	61	19

We observed that, for the tested ratings, the evolutionary algorithm achieves a better objective function value (lower Objective) in less time (faster Run Speed). From this comparison, we conclude that Excel's evolutionary algorithm is a better approach for using the SSFM to determine optimal sea and shore tour lengths.

CNA's Discrete-Event Simulation Approach to SSF

Discrete-Event Simulation (DES) is a powerful tool to analyze complex and dynamic systems that are subject to randomness and uncertainty [2]. CNA analysts developed a DES model in ExtendSim 9.1 to study SSF policies and the impact of PST changes on sea and shore manning in 2014. This original model was tested on only one rating (B650: CS). The original DES-SSF model could track all sailors by their sea and shore tour experience and observe the impact of PST change on short- and long-term sea manning [3]. However, the model lacked five key factors:

1. *Gender.* In this study, we improved the model by including a gender-specific rate. The model also takes percentage of female accessions as an input.

2. *Advancement.* In the previous model, sailors could be tracked only by sea and shore experience. We included the "advancement feature" to the improved model. The model takes average advancement rates from any paygrade to the next one as an input with consideration of minimum time in grade and high-year tenure.

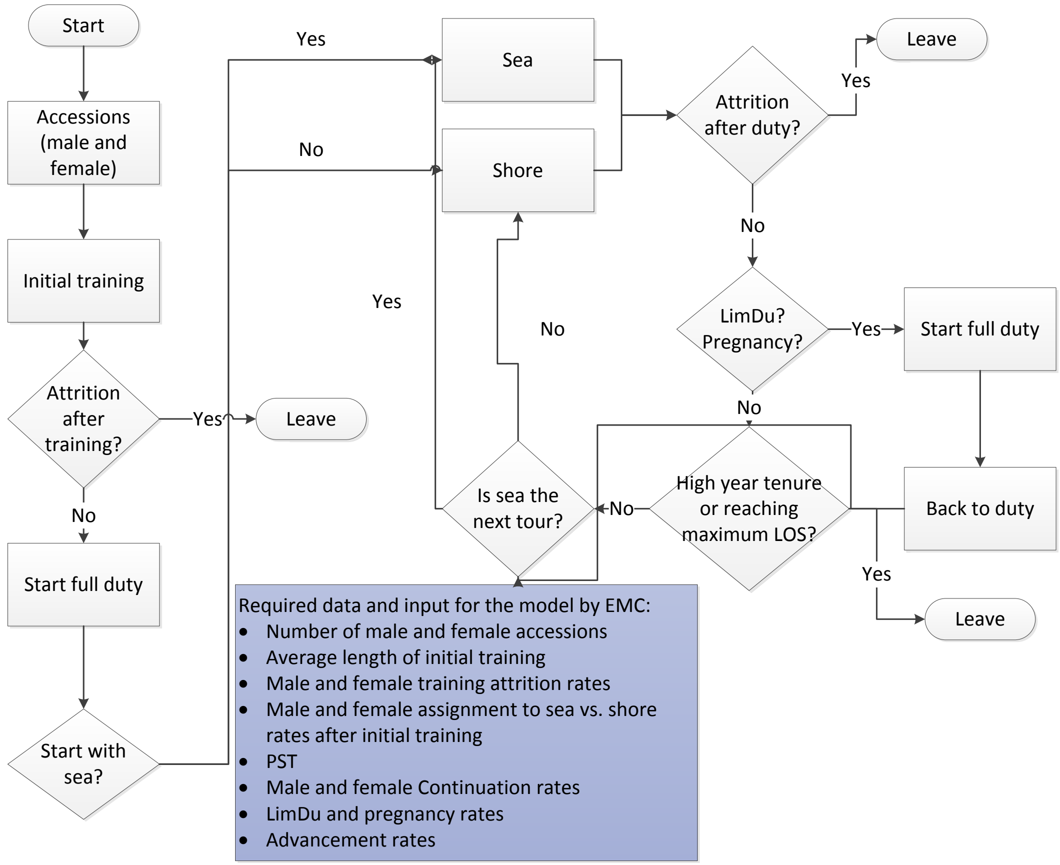
3. *Billet structure.* Because we did not have paygrades in the previous model, we could not use the actual Navy billets. The current model includes all Navy billets (sea, shore, and student billets).

4. *Initial distribution.* Similar to the Navy's SSFM, our original model assumed that sailors are assigned to sea after their initial training. We introduced the flexibility of assignment to shore after the initial training. We obtained actual Navy data on those assignment decisions and incorporated them in the model. As a result of this change, we observed that the impact of PST change can be very different on communities in which a considerable portion of sailors start with shore duty, such as Aviation Machinist's Mates (AD).

5. *LimDu, pregnancies, and delays in transition between duties.* We included these in the most recent DES-SSF model.

The flowchart in Figure 1 shows the processes we simulated in DES-SSF.

Figure 1. Processes modeled in DES-SSF



To test the validity of the model and understand the impact of PST change, we selected nine ratings and modeled them thoroughly. In the next section, we explain the logic behind selecting these particular ratings.

How Ratings Were Chosen

To analyze our modifications to the model, we needed to select a group of EMCs that were representative of the effects we were trying to examine. We met with key Navy subject matter experts (SMEs) from OPNAV N132, BUPERS 32, Program Management Office (PMO), Fleet Forces Command (FFC) and Pacific Fleet (PACFLT) to determine baseline criteria for rating selection. We used the SME input and model refinement (see Table 2) to select the communities to study.

Table 2. Refined EMC selection criteria

Changes Under SSF	One change under SSF—increasing
Gender Representation	30 percent or higher female accessions in FY 2015 and 2016 if possible
Sea/Shore Centricity	50% or greater sea centric
Enlisted Program	Representative sample of lengths of contract (4/5/6-year contracts); include a PACT-in rating
Mission Area	Representative sample of each: Air, Surface, and Subsurface

Changes under SSF

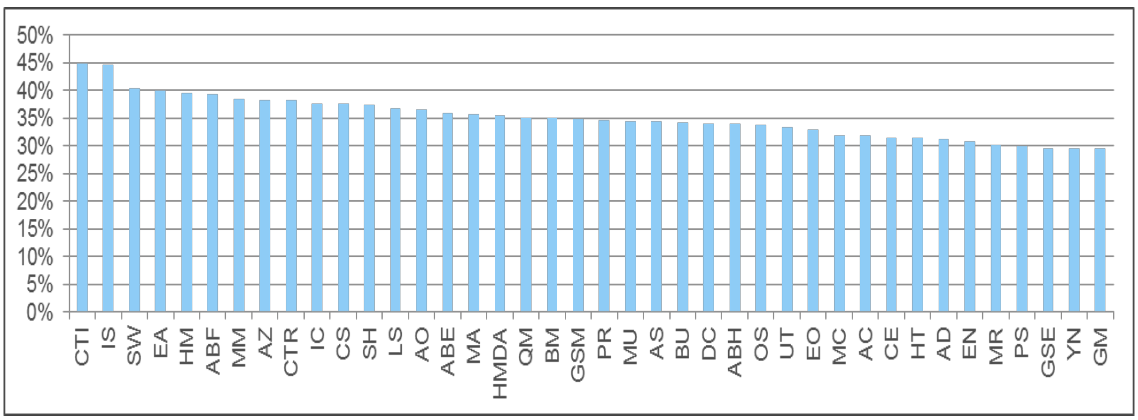
We first looked for EMCs with multiple PST changes during multiple revision cycles under the new SSF policy. After further consideration, however, we determined that EMCs that experienced multiple changes from revision to revision were too dynamic to test a PST change effect. The effect needed to be isolated to one PST change. Therefore, we changed our approach and included only those EMCs that had experienced one PST change. We further narrowed this to one PST change in the 2011 revision with no subsequent changes in later revisions. Then we selected EMCs with increasing PSTs, meaning the PST change involved an increase in the number of months required at sea. This limited the number of aviation EMCs that were included because, although most aviation communities had increasing PST events in the 2011 revision, most of these were revised again, mostly decreasing the PST, in the 2012

revision. Still other aviation communities realized no PST changes in 2011 revision. The exception was the AD community, which met the criteria.

Gender representation

The Navy continues to increase the number of women in its enlisted force. This has caused concern from the fleet because female sailors traditionally have lower continuation, fewer sea tour assignments, and lower completion rates. The prevailing thought is that increasing the number of women in an enlisted community amplifies the impact on PST returns. To evaluate the future risk to the Navy, we looked at male-to-female accession numbers. The percentage of female accessions has risen from 23 to 25 percent, which has resulted in a growing number of EMCs with 30 percent or more female accessions. We used the Navy's Rating Phasing Matrices for the FY 2015 and FY 2016 Navy accession plans to determine where the Navy had targeted these increases. In FY 2015, there were 28 EMCs with 30 percent or more female accessions. That number grew to 40 EMCs in the FY 2016 plan. Figure 2 shows FY 2016 EMCs with 30 percent or greater female accessions.

Figure 2. EMCs with 30 percent or greater female accessions



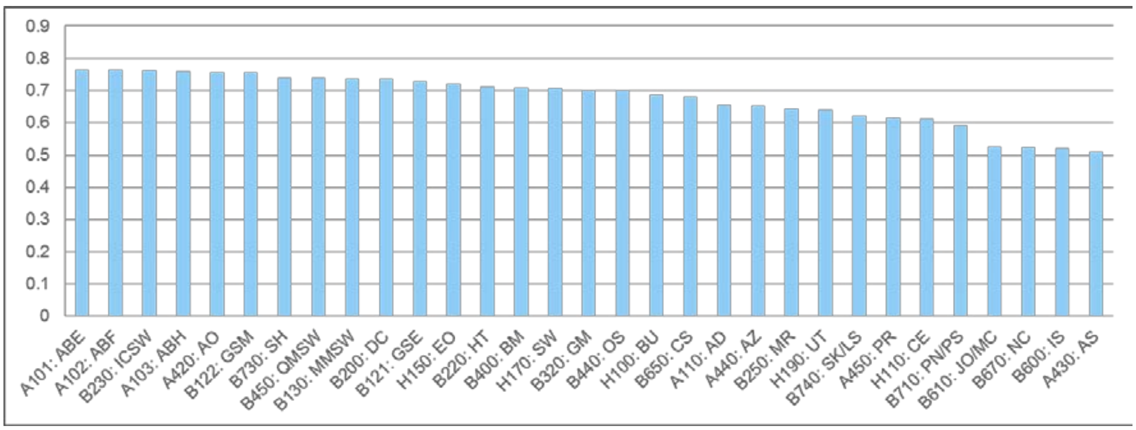
Source: Rating Phasing Matrix FY16 Enlisted Accession Plan.

When selecting the EMCs for use in our simulation, we strove to include as many EMCs as possible that met the 30 percent or greater female accession criteria. This was not possible for the subsurface communities because the Navy just recently opened enlisted subsurface communities to women.

Sea/shore centricity

Sea centricity is a ratio of sea and shore billets. The more sea billets an EMC has, the greater its sea centricity. To determine sea centricity, we used Navy Total Force Manpower Management System (TFMMS) sea and shore billet data. We originally set a 75-percent sea-centric floor. We adjusted this down to a 50-percent or greater sea-centric floor to allow for the inclusion of enlisted communities with shore first rotations. We then compared sea-centric communities against those ratings with 30 percent or greater female accessions. Figure 3 shows the 31 communities that fit both criteria.

Figure 3. EMCs with 50 percent or greater sea-centric and 30 percent female accessions



Source: TFMMS and Rating Phasing Matrix FY16 Enlisted Accession Plan.

Enlisted program

As the Navy has increased its technical complexity, training pipelines for its sailors have grown longer. Longer training pipelines mean less time at sea, so the Navy lengthened service contracts for sailors in these technically complex communities. The Navy's premise is that lengthening the contracts to five and six years would allow the Navy to maintain PST returns even though training time had increased. We decided to evaluate this premise by including communities representing all contract lengths in our analysis.

Professional Apprenticeship Career Track (PACT) sailors enter the Navy under a four-year contract and are rated to an enlisted community between 12 and 24 months, with an average of rating at 14 months. Once PACT sailors are rated, they maintain

their original four-year contract obligation, unless they attend an A-school. Currently, only 9 percent of PACTs attend A-school. Ratings such as ABH and BM have high PACT-in quotas and are now five-year contract EMCs. However, most PACT sailors who rate as BMs do not attend A-school and, therefore, maintain their original 48-month contract. The initial PST of a rated BM is 53 months. These BMs enter the Navy with 60-month contracts and reach the fleet at approximately 5.5 months, so the Navy can realistically expect them to complete their 53-month PST. However, a PACT sailor starts with a 48-month contract, reaches the fleet at approximately 5 months, and rates as a BM at 14 months. As a result, the Navy can expect them to complete only 43 months of their initial sea tour, of which only 34 months is as a BM. This is approximately 19 months less than the five-year BM accession estimated to complete in-rate and, overall, 10 months less sea-time.

To test the effect of the PACT issues, we included EMCs in our selected ratings that have PACT-in quotas.

Mission area

For any analysis on enlisted manning and policies, it is important to include representatives from the Navy's key mission areas. To that end, we included in our selected ratings EMCs for each of the main mission areas: air, surface, and subsurface. This allowed us to assess the impact of SSF policy and PST length changes across the Navy's main mission areas.

Selected EMCs

The EMCs in Table 3 were selected because they were subjected to a single policy change of increased PSTs in 2011 and met more than one of the selection criteria above. Final selection criteria for our test communities included mission area representation, PACT-in quotas, female accession percentage, sea centricity, and enlisted program (contract length). We also included a community with high rates of sailors with a first tour of shore rotation. We determined that these communities had the best cross-representation of the enlisted force that would allow us to assess the SSF PST change effect.

Table 3. Selected EMCs

EMCs	Mission area	Contract length	PACT-in	% Female accessions (FY16)	Sea centricity
AD	AIR	4yo	Yes	30%	65%
CS	SURF	4yo	Yes	38%	68%
DC	SURF	4yo	Yes	34%	74%
FT	SUB	5yo	No	N/A	75%
GM	SURF	4yo	Yes	30%	70%
LSSS	SUB	4yo	No	N/A	64%
MR	SURF	4yo	No	30%	64%
STG	SURF	4yo/6yo	No	27%	70%
STS	SUB	5yo	No	N/A	74%

In the next section, we discuss the results of PST change on each of these ratings and explain the reasons behind the observations in greater detail.

DES-SSF Analysis and Results

As the first step toward understanding the impact of PST change on sea manning, we conducted a comprehensive statistical analysis of the Navy's data on sea and shore tour length. We collected data on tour length from 2010 to 2014 and controlled for gender, loss or stay, and the assigned PST during that timeline. All EMCs selected for this study have at least one PST change in 2011. To analyze the data, we looked at sea and shore tours that ended in each fiscal year and then recorded the length of that tour.

Given the change of PST in September 2011 and assuming nine months of grandfathering, a tour was assigned to the old PST if it ended before May 2012; otherwise, we assumed the assigned PST is the new one.

The statistical method and the results of this analysis are presented in detail in Appendix A. In most cases, a PST increase did not result in a significant increase in tour length. More investigation is needed to understand why the average sea tour length did not significantly increase as the PSTs were increased.

The next step toward quantifying the impact of PST change was to develop the DES-SSF as described by the processes illustrated in Figure 1. Employing this model, we tested five scenarios:

1. Nonstochastic PST baseline (S1): In this scenario, there is no PST change (i.e., the PSTs remain the same throughout the simulation run).
2. Nonstochastic PST with change (S2): In this case, we input the original PST before September 2011 and the new PST afterward. The model considers nine months of grandfathering in calculating tour length for each sailor.
3. Shorter shore duty (S3): In this scenario, we allow the Navy to pull sailors from shore if the manning at sea is less than 100 percent, and if the sailors have been at shore for at least 24 months. The goal of this scenario is to compare the result of an increase in PST (S2) versus a decrease in shore tour length on manning.
4. Stochastic PST without change (S4): Even in the absence of PST change, sea tour lengths are highly variable. We used the Navy's data and built an empirical distribution of sea tour lengths before September 2011. Instead of

generating PRDs in the model, we fed the actual data to see the manning levels, given this variability.

5. Stochastic PST with change (S5): This scenario is similar to scenario three, but we fed the model with two distinct empirical distributions for sea tour length—one before the September 2011 change and one after the change (with consideration of grandfathering).

Throughout this paper, the metric of interest for all analyses is sea manning, which is calculated as inventory at sea divided by sea billets for each payband. The paybands in this model are E1-E4, E5-E6, and E7-E9. We track the impact on manning for each year after the policy change up to 10 years, and then, in steady state, we average manning from 10 years after the change to 30 years after the change, holding all parameters (such as advancement rates, continuation rates, and PST) fixed.

Overview of the results

The uniqueness of each community suggests that a single policy will not have the same impact for all communities. Increasing sea tour length may result in better sea manning in one community, and for a different community shorter shore tours can be more effective in improving sea manning (inventory divided by billets). Table 4 summarizes the result of the five simulated scenarios on each EMC's sea manning. Note that sea manning in this study is defined by inventory divided by billets.

Table 4. Summary of DES-SSF results

EMC	E1-E4					E5-E6					E7-E9				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
AD	0.96	0.98	0.85	0.85	0.88	0.87	0.94	1.00	0.80	0.83	0.85	0.90	1.00	0.82	0.86
CS	0.90	0.91	0.75	0.75	0.76	0.85	0.93	0.99	0.68	0.72	0.91	1.01	0.90	0.83	0.83
DC	0.91	0.93	0.73	0.73	0.77	0.87	0.97	0.99	0.66	0.71	1.08	1.20	1.01	0.79	0.91
FT	1.22	1.26	1.04	1.04	1.08	0.87	0.96	1.05	0.76	0.83	1.05	1.22	1.06	0.89	1.02
GM	0.91	0.94	0.79	0.79	0.81	0.76	0.96	0.69	0.69	0.71	0.86	1.08	0.87	0.87	0.86
LSSS	0.86	0.97	0.78	0.78	0.82	0.75	0.93	0.89	0.73	0.78	0.99	1.03	0.91	0.86	0.88
MR	1.61	1.61	1.39	1.39	1.40	0.76	0.83	0.90	0.70	0.69	1.51	1.68	1.68	1.62	1.60
STG	0.83	0.83	0.72	0.72	0.73	0.89	0.96	1.01	0.72	0.73	1.09	1.35	1.35	0.97	1.02
STS	0.93	0.94	0.79	0.79	0.79	1.08	1.15	1.15	0.98	1.04	0.84	1.10	0.82	0.88	0.92

Here are a few key observations:

- There is a natural variation in sea and shore manning rates even in the absence of policy change. This variation is a result of complex dynamics between several stochastic events, such as attrition, advancement, or LimDu. The larger a community, the less variation we observe. There is more variation in manning level at the senior paybands, such as E7-E9, compared with junior paygrades because of the number of sailors in each of those paygrades. For example, the Culinary Specialist community is relatively large, with more than 2,300 E1-E4 sailors on sea duty (average of FY 2010 to FY 2015). As Figure 4 shows, there is variation in manning, even when all the rates are held fixed for 10 years. Figure 5, however, shows the variation in manning for E7-E9 FTs if the number of E7-E9 sailors at sea were less than 150.

- There are differences in long-term and short-term impacts of PST change. It will take time for any policy change to be fully effective. The focus of the SSFM is on the steady state (i.e., long-term effects of change). In the DES-SSF, we look at the life cycle of change.

- First assignment matters. The SSFM assumes that all sailors start their full duty with a sea assignment. In reality, there are many communities with a significant number of (nonstudent) E1-E4s starting their Navy careers ashore. In general, the larger that number, the less the improvement in sea manning from increasing the first sea PST.

- The policy of pulling sailors from shore after 24 months is not necessarily beneficial in improving sea manning for communities with a large number of sailors who start with sea duty. In such communities, sailors at sea and at shore tend to have different paygrades. In the steady state, when sailors are distributed initially to both sea and shore, the Navy will have a more ideal combination of years of service (YOS) and paygrade in both duties, which can help tremendously when improving sea manning by acquiring sailors from shore duty.

- The mismatch between the contract length and the length of initial training combined with the first sea tour is crucial. For example, for ADs, the initial training averages about eight months, followed by a sea or shore duty. Before the 2011 PST change, the first sea tour of ADs was 42 months (it is currently 48 months). As a result, ADs were still in the middle of their first sea tour by the end of their first obligation of four years, even without an increase in PST. The increase of 6 months in their first sea tour would not have been applied to the sailors who did not reenlist (about 30 percent of the sailors). Considering that 35 percent of ADs start their full duty ashore, the impact of this sea duty increase of 6 months will become even less significant.

Figure 4. CS's E1-E4 sea manning

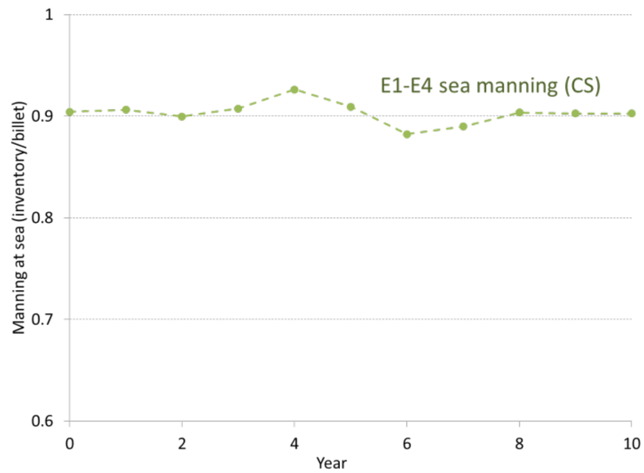
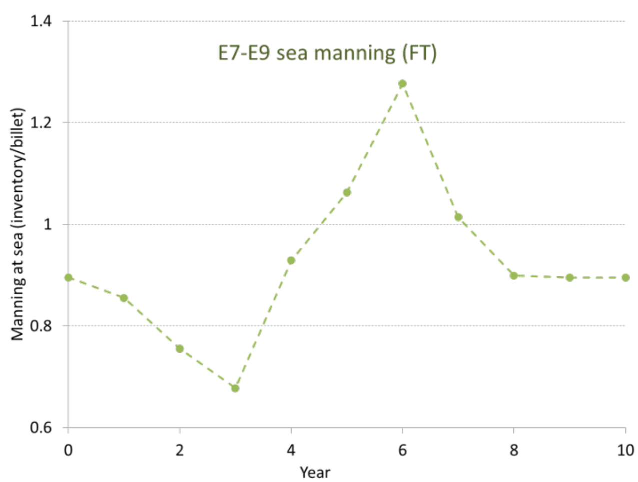


Figure 5. FT's E7-E9 sea manning



In the next subsections, we present the DES-SSF results for three ratings: Aviation Machinist's Mate (AD), Culinary Specialist (CS), and Logistics Specialists Submarine (LSSS). The results for the remaining EMCs selected in this study are presented in Appendix B.

Results for Aviation Machinist's Mate (AD)

ADs are aircraft engine mechanics, a crucial community in the air mission area. AD sailors inspect, adjust, test, repair, and overhaul aircraft engines and propellers. They attend a 9-week A-school and a follow-on C-school for a specific aircraft platform or aviation intermediate maintenance duty (AIMD). Their average street-to-fleet (STF) time is 7 months. Approximately 39 percent of AD sailors report to a shore tour for their initial assignment. ADs require a line score (VE+AR+MK+AS) of 210 on the Armed Services Vocational Aptitude Battery (ASVAB).[4] The ASVAB is a multiple-aptitude battery that measures developed abilities and helps predict future academic and occupational success in the military.

ADs enter the Navy under a four-year contract. AD is considered a shore-centric rating and is currently manned at 102 percent. However, manning at sea remains at 96 percent, with shore-manning considerably higher at 115 percent. As such, their current promotion opportunity is below the all Navy (ALNAV) percentages for all promotion categories [4]. The average AD will promote to E4 at 2.4 years of service and to E5 at 4.8 years of service.[5] Although the AD community normally accepts PACT sailors, they have restricted opportunity in FY 2016 due to overmanning. AD has a large female sailor population that is expected to grow in the future, with 30 percent of all AD accessions being female in FY 2016.

Table 5 shows the sea/shore flow for ADs. As shown, the first and second sea tour lengths of ADs increased by six months. We did an extensive statistical analysis on the Navy's sea tour length data for all sea tours completed between 2010 and 2014 (see Appendix A).

[4] The ASVAB produces several line scores to determine qualification for Navy jobs. Navy line scores are derived from the following categories: VE – verbal expression, WK – word knowledge, AR – arithmetic knowledge, MK – math knowledge, AS – auto and shop, MC – mechanical comprehension, GS – general science, and EI – electronics information.

[5] The rates reflect current promotion rates to E4 and E5 in terms of average years of service and are published by the Navy for each community on the Personnel Command page Community Career Path link. These numbers are an average and were not validated by independent analysis of actual Enlisted Master Record (EMR) data. The promotion rates used in our DES-SSF model are taken from actual EMR data from 2012 to 2014.

Table 5. Aviation Machinist Mate (AD) sea/shore flow

Tour	1st	2nd	3rd	4th	5th	6th	7th
SEA_{old}[a]	42	42	36	36	36	36	36
SEA_{new}[b]	48	48	36	36	36	36	36
SHORE	36	36	36	36	36	36	36

a. SEA_{old} represents old PSTs.

b. SEA_{new} represents new PSTs.

Sea manning of ADs has increased overall for all paybands (see Figure 6 through Figure 8). A few interesting and nontrivial patterns are observed:

- Even though the PST increase was employed for only the first and second sea tours, an increase in sea manning for E7-E9 was observed, which may seem unintuitive since sailors in those paybands tend to be serving their third sea tour and beyond (see Figure 8). However, because more than 30 percent of ADs start their full duty assignment ashore, it is possible for them to be in the E5-E6 payband by their first sea tour and in the E7-E9 payband by their second sea tour. These observations validate the need to include all the details of advancement in any model that attempts to understand the nature of these policy changes.

- A significant increase in the E5-E6 manning from year 5, after the policy change, until year 8 (see Figure 7) is observed for the same reason described above, since E5s are observed serving both the first and second sea tours.

- The full effect of PST change on sea manning will not be realized instantly; it takes around four to five years.

As expected, increasing sea manning while keeping the total inventory constant will result in decreased shore manning. We present the results of this analysis in Appendix C.

Figure 6. AD's E1-E4 sea manning under the old and the new PST

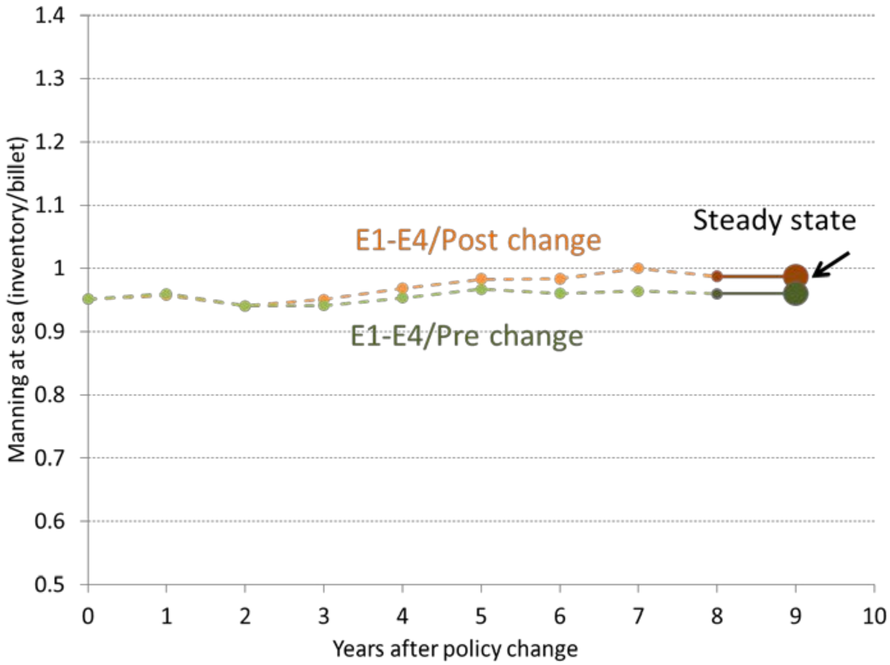


Figure 7. AD's E5-E6 sea manning under the old and the new PST

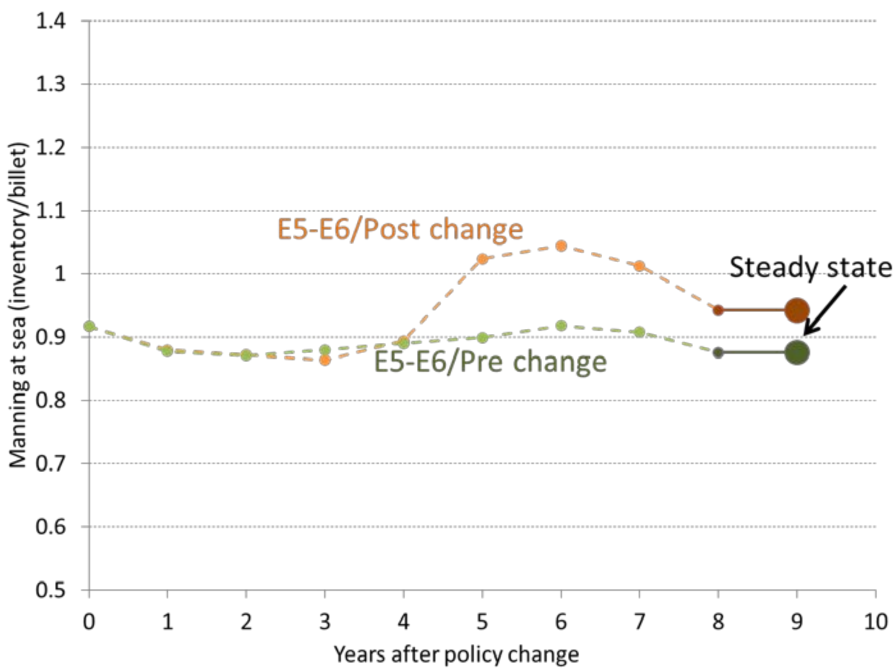
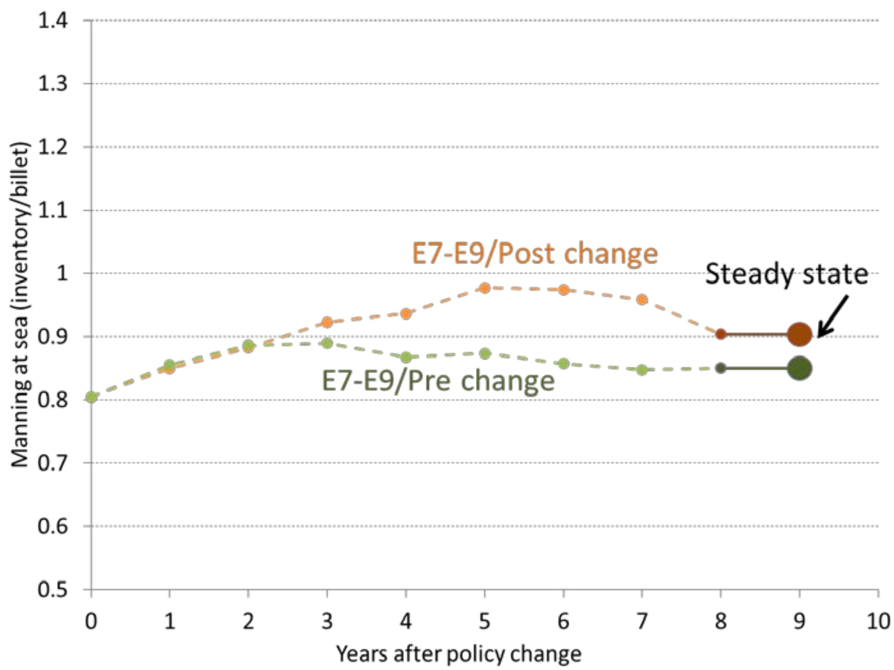


Figure 8. AD's E7-E9 sea manning under the old and the new PST



As mentioned previously, roughly 30 percent of ADs start their full assignment ashore, resulting in a diverse combination of all paygrades and LOSs at both sea and shore. Therefore, we also tested the policy of pulling sailors from shore if the manning at sea is less than 100 percent only if the sailors have the right paygrade and they have been at shore for at least 24 months (this policy was examined under the old PST). The results of this analysis are presented in Figure 9 through Figure 11. Further analysis is necessary to understand this policy, particularly its impact on retention, advancement, and other key elements. However, for the AD community, this policy tends to perform better than the policy involving a PST change.

Figure 9. AD's E1-E4 sea manning under the new PST vs. the shorter shore length policy

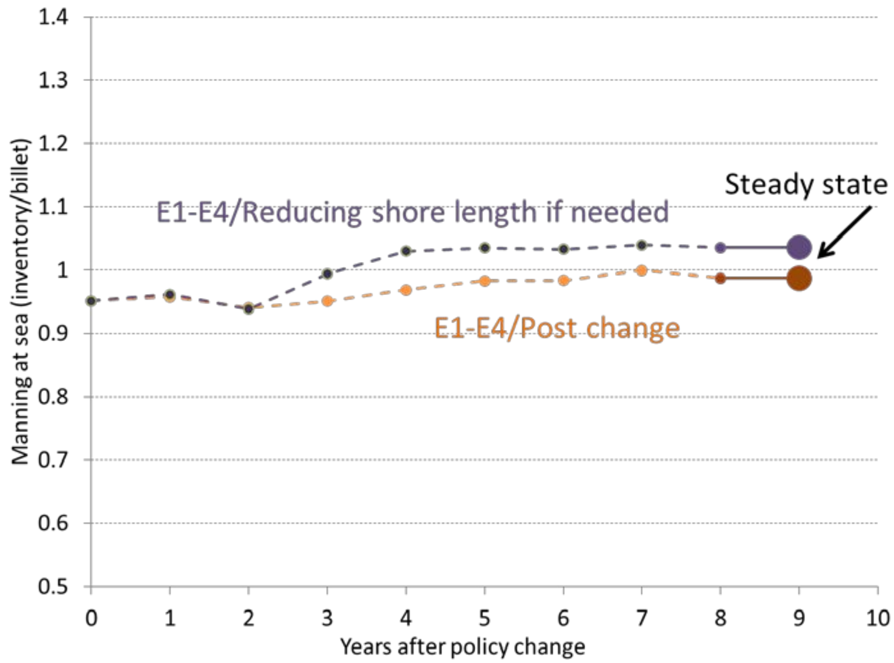


Figure 10. AD's E5-E6 sea manning under the new PST vs. the shorter shore length policy

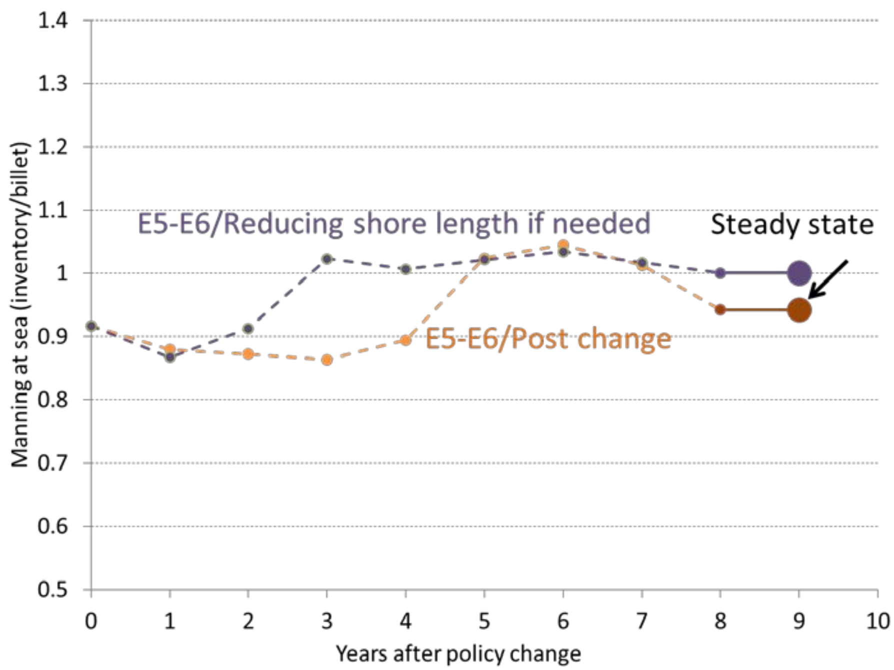
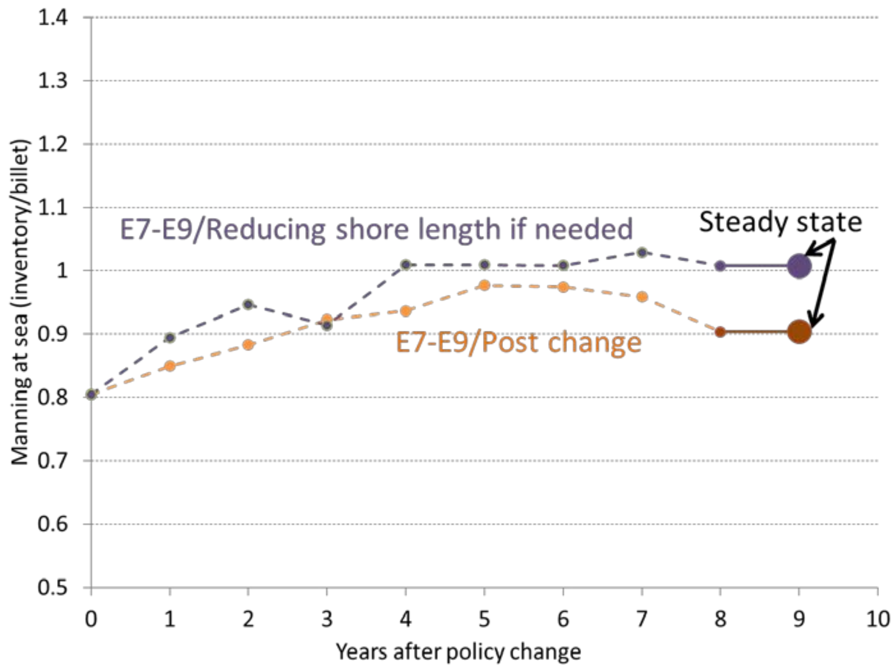


Figure 11. AD's E7-E9 sea manning under the new PST vs. the shorter shore length policy



Results for Culinary Specialist (CS)

CSs are responsible for all aspects of the dining (shipboard mess decks) and shore duty living areas. A CS is considered a surface mission area community in the supply subcategory, but CSs are also assigned to aviation and shore commands. As Navy galleys were contracted out, the reduction of CS billets ashore has led to increasing sea-centricity for this community. CS sailors enter the Navy on a four-year contract, require an ASVAB line score (VE+AR) of 89, and have an average STF time of 5.3 months. The CS community is currently manned at only 90 percent at sea and 115 percent ashore, with overall community manning at 98 percent . This community has unrestricted opportunity for reenlistment and conversion for PACT and RC sailors, but opportunities for promotion are above ALNAV percentages only for the E5 and E8 paygrades. The average CS will promote to E4 at 2.3 and to E5 at 4.5 years of service. CS has a large female sailor population that is expected to grow in the future, with 38 percent of all CS accessions being female in FY 2016. Table 6 shows the sea/shore flow for CSs.

Table 6. Culinary Specialist (CS) sea/shore flow

Tour	1st	2nd	3rd	4th	5th	6th	7th
SEA_{old}	48	48	36	36	36	36	36
SEA_{new}	54	54	36	36	36	36	36
SHORE	36	36	36	36	36	36	36

The conjecture based on an initial observation suggests that the shortened shore tour policy did not have the same impact of increased sea manning for CSs. This is because the majority of CSs start their full duty at sea; consequently, shore duty has a different arrangement of paygrades and LOSs. In this situation, shore duty cannot be used as a reservoir to supply sea manning shortages. The results of this analysis are presented in Appendix B.

Under the new PSTs (first and second sea tours increased from 48 to 54 months), we observe an increase in sea manning, although it is not statistically significant (see Figure 12 through Figure 14). From the Navy data used in the model, we observed that more than 35 percent of CSs leave at YOS 3. Given this continuation rate, the six-month increase in sea tour will be applied to only the 60 to 65 percent of the sailors who are staying beyond YOS 4.

Figure 12. CSs' E1-E4 sea manning under the old and the new PST

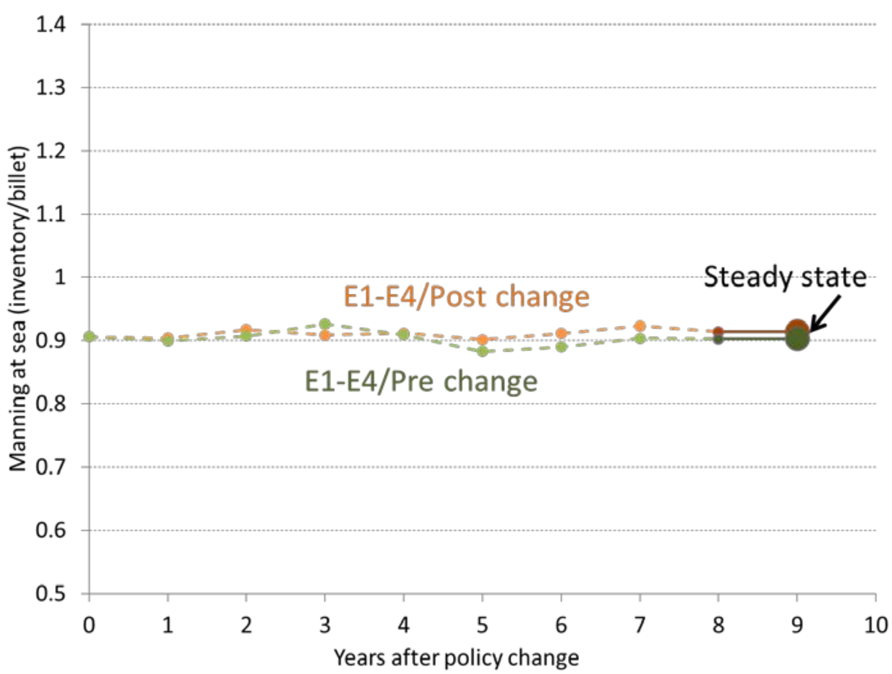


Figure 13. CSs' E5-E6 sea manning under the old and the new PST

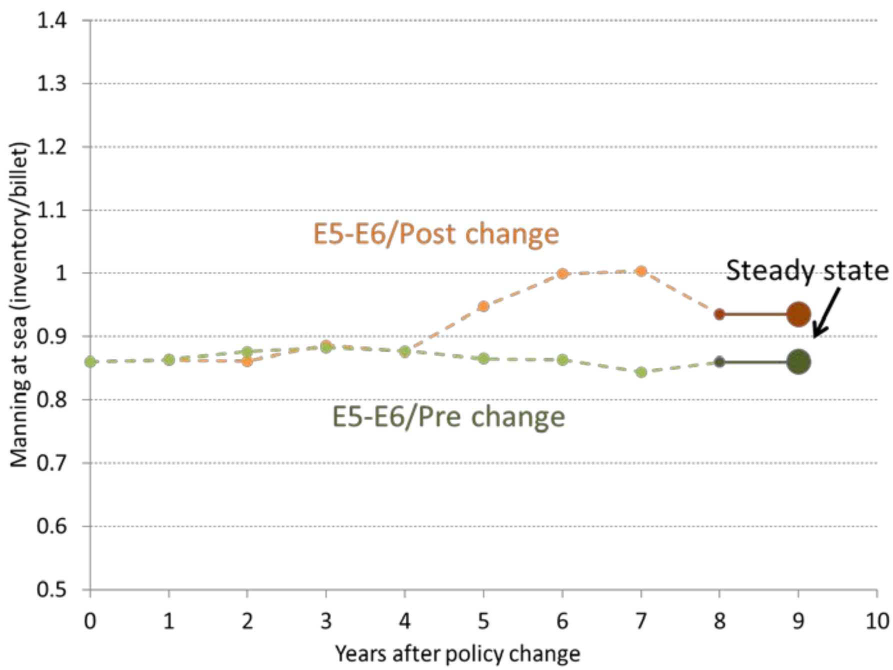
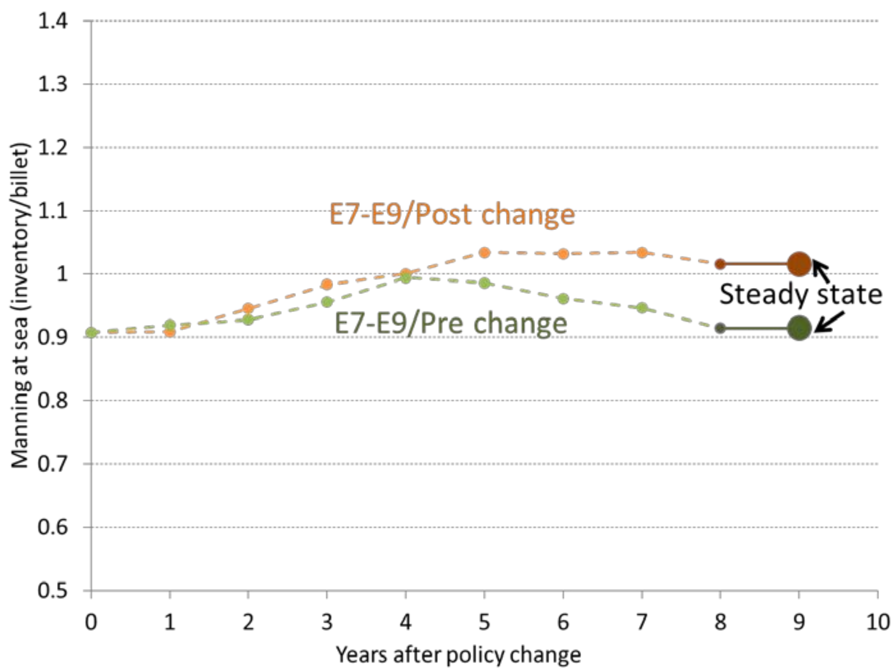


Figure 14. CSs' E7-E9 sea manning under the old and the new PST



Results for Logistics Specialist Submarine (LSSS)

LSSS sailors receive extensive training in the management of repair parts and consumables for submarines, submarine support, and shore bases, and in maintaining million-dollar operating budgets. LSSS is a subsurface mission area community and is considered shore-centric. LSSS requires an ASVAB line score (AK+MK+EI+GS or VE+AR+MK+MC) of 200 and has a four-year contract. It has an average STF time of 8.6 months. Current LSSS manning is at 104 percent, with sea manning at 118 percent. Manning at sea for paygrades of E4 and below is particularly high at approximately 160 percent. Promotion opportunities for LSSS are consistent with the ALNAV percentages in all promotion categories with the exception of E7, which is significantly higher [4]. The average LSSS will promote to E4 at 2.2 and to E5 at 4.7 years of service. LSSS is expected to have female accessions in FY 2017, but no female accessions were included in the FY 2016 plan. This community does not have PACT quotas. Sea-shore flow for LSSSs is shown in Table 7.

Table 7. Logistics Specialist Submarine (LSSS) sea/shore flow

Tour	1st	2nd	3rd	4th	5th	6th	7th
SEA_{old}	36	36	36	36	36	36	36
SEA_{new}	48	42	36	36	36	36	36
SHORE	36	36	36	36	36	36	36

LSSS can be viewed as a success story of PST change. The 2012 PST change resulted in manning improvements at sea for all paybands (see Figure 15 through Figure 17). Two main factors contribute to this positive impact. First, the length of the first sea tour, combined with initial training (average training is only five months), was shorter than the length of obligation; thus, increasing sea tour length changes the length of stay at sea for a greater number of sailors. Second, more than 70 percent of LSSS sailors stay in the Navy after their first obligation, meaning more sailors stay at sea longer, thereby improving sea manning.

Figure 15. LSSS E1-E4 sea manning under the old and the new PST

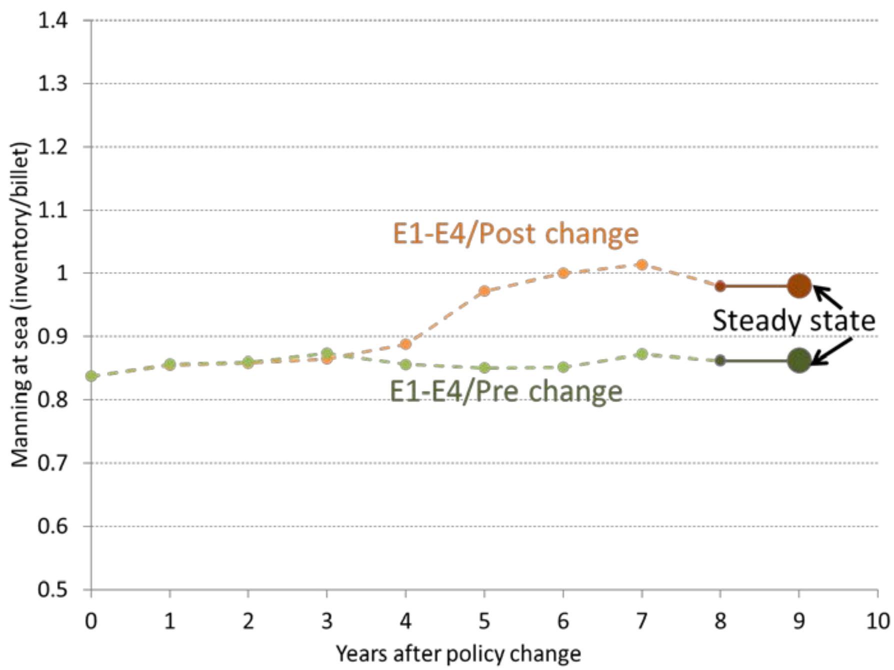


Figure 16. LSSS E5-E6 sea manning under the old and the new PST

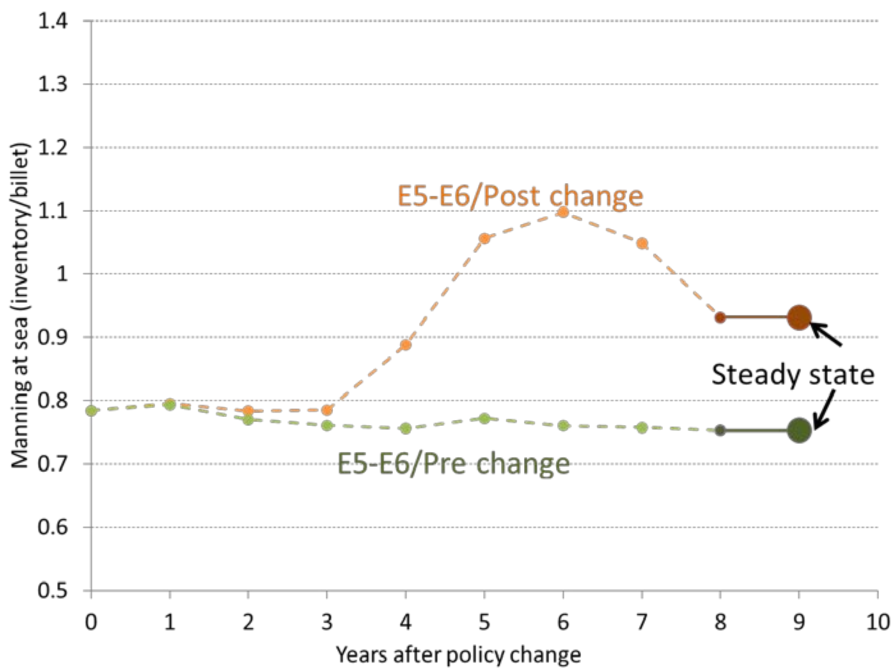
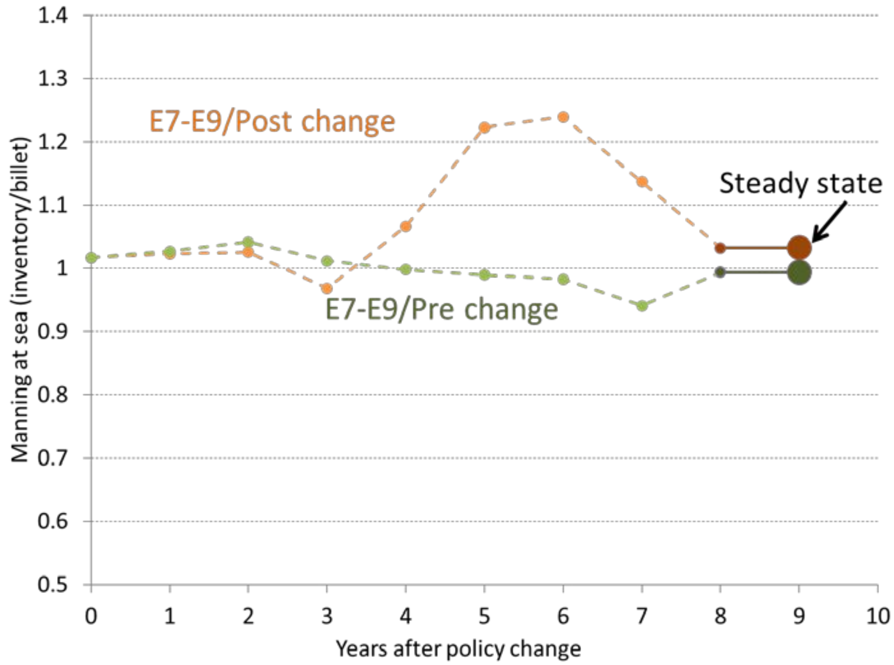


Figure 17. LSSS E7-E9 sea manning under the old and the new PST



Recommendations and Future Work

General findings

The relationship between manning at sea and shore and such variables as attrition, advancement, and LimDu is highly complex. The inherent variability built into this system should be acknowledged because it is unavoidable. Regardless of any policy implemented by the Navy, and regardless of how well organized it is, manning variation will always exist due to natural heterogeneity among communities and among individuals within communities. However, it is possible to control this natural variation through improved policies over the long term. The predicament is that it is necessary to realize and quantify the short-term impacts of any change because it can take a relatively long time for a system to achieve the steady state.

Each community possesses unique characteristics, so no universal policy should be applied across all communities. A diverse vector of technical, manpower, and duty-related variables affects the effectiveness of policies. As observed in the discussion of the results, decreased shore tour lengths can improve manning in both the short and long terms for ADs but not for CSs. Improving manning for the E1-E4 paygrades may be more feasible through revised length of contracts rather than any change in PST or shortened shore duty.

Policies involving shortened shore duty require less time for their full effect to be realized. On the contrary, policies involving changes in PST take more time to be fully effective, as a result of grandfathering and other constraints.

Recommendation for SSFM

The goal of this study was to evaluate the Navy's Sea/Shore Flow Model and propose practical ways to enhance the model's performance. We started this task by collecting the Navy's data on key inputs of the model, including continuation rates, advancement, average length of initial training, and PSTs. We enhanced CNA's DES-SSF, which was originally developed in 2014, to compare its results with the SSFM.

The objective of the SSFM is to minimize total sea time and deviation for user-defined ideal sea tour lengths as constrained by the sea EPA of the communities. It is

a user-friendly, Excel-based tool. Our findings suggest that, for the most part, the SSFM works as advertised, but it has a tendency to overestimate the impact of PST change on sea manning, compared with the results from CNA's DES-SSF. The SSFM does not address several key characteristics of the manning problem, such as advancement. In our efforts to enhance CNA's DES-SSF, we found that including the following key factors can improve the performance of sea/shore flow modeling and the validity of the results of such modeling:

1. *Sea versus shore initial assignment:* Including the feature of assigning sailors to sea vs. shore can change the performance of the SSFM. In reality, changing the sea tour length will not be as effective when a portion of sailors in that community begin on shore duty because not as many sailors will be subject to the PST change. In that case, we recommend adding a feature to the SSFM that assigns a percentage of sailors to shore immediately following training.

2. *Advancement:* The current SSFM does not model advancement and its rather complex impact on manning. Because the billets that are input to both the SSFM and the DES-SSF are categorized by paygrades, it is beneficial to add features of advancement to the model, such as average advancement rates, high-year tenure, and minimum time in grade.

3. *Short-term versus long-term impacts of change in PST:* SSFM is a steady-state model; it does not provide any insights of manning changes between the time of policy change and achievement of the steady state. It also does not give any information about how long it takes to achieve the steady state. Our findings confirm that the time and the pattern of reaching the steady state vary among the communities.

4. *Alternative policies:* Considering other policies, such as shorter shore duty as opposed to longer sea duty, can be beneficial in improving sea manning.

Future work and key areas to enhance DES-SSF

Modeling the stochasticity of sea and shore tours based on actual historical data can enhance the performance of the DES-SSF. We do not completely understand the reason, but, when the DES-SSF was evaluated under stochastic sea and shore tours (scenarios four and five), the average sea manning was consistently lower than other scenarios. There is a need to understand the data better and the underlying causes resulting in the observed variability in sea and shore tour lengths.

The current DES-SSF model is capable of incorporating several key factors, such as advancement, continuation, and stochastic sea and shore lengths. One of the key improvements to the current DES-SSF would be to modify the advancement process and validate that it represents how the Navy advances sailors. In the current model, advancement rates are constant through time. Therefore, the only factors affecting a sailor's promotions are:

- The advancement rate
- The last promotion time (to calculate the minimum time in grade)
- High-year tenure

However, the advancement process involves complexity beyond just these three variables. The Navy can regularly change the advancement rates to promote to vacancies. Our model does not take into account "promotion to vacancies." The DES-SSF can be modified to account for the aforementioned parameters and factors, as well as to look at the vacancies and promote sailors based on these vacancies.

Another potential improvement that can be applied to both the SSFM and the DES-SSF is the possibility of back-to-back sea and/or back-to-back shore tours. The SSFM assumes that sailors start their first full duty at sea, followed by shore, and so on. In the DES-SSF, sailors do not have to start with sea duty. In fact, the model takes the historical shore assignment rates from the Navy as an input, using these data as the "initial" assignment. However, the model does not have the capability of assigning sailors to back-to-back sea or shore tours. Adding flexibility in assignment will improve the fidelity of both models in representing the real world.

DES-SSF can be further enhanced by including other variables beyond PSTs, such as number of accessions, percentage of female accessions in each rating, and continuation rates. By including more features, we will be able to track the effect of each variable on sea and shore manning (or other desirable outputs), holding everything else constant.

Appendix A: Statistical Analysis

To assess the effectiveness of the new policy in lengthening the duration of sea tours, an independent-samples t-test was conducted. The independent-samples t-test is used when the research interest is to detect a difference between two independent groups on a continuous outcome variable [5-7]. Using the data available from the Sea/Shore Flow Model, the continuous outcome variable is the average length of sea tour, and the grouping variable was pre- and post-policy change (cut off at May 2012). Although sea tour data from the same sailor may be included in more than one sea tour, an independent-samples t-test was employed under the assumption that the length of a sailor's sea tour is independent across different sea tours. For example, we may have information about sea tours 1 and 2 from Sailor A, but we proceed with the assumption that the amount of time Sailor A served in sea tour 1 is independent of that served in sea tour 2. In addition, since our interest was to investigate whether the duration of sea tours increased after the new policy, the research hypothesis tested was: Did the sea tour length for sailors in a given sea tour increase after the new policy was implemented? Hence, one-tailed p-values are reported in the results.

For each community, we conducted a t-test to examine differences in average sea tour lengths from pre- to post-policy implementation for sea tours 1, 2, 3, and 4 separately for the entire community. Differences were assessed for each community regardless of gender, as well as separately for male and female sailors. This was done to examine whether discrepancies in the average lengths of sea tours existed across gender.

The differences between standard deviations of pre- and post-policy implementation groups across sea tours and communities were trivially different, so a pooled t-test was used. For a pooled t-test, the test statistic is calculated using an estimate of the standard error that incorporates the sample sizes and standard deviations of both groups, referred to as the pooled standard error [5-7]. Had the standard deviations been very different across groups, or had the standard deviation of one group been double that of the other group, a nonpooled method would have been used.

Due to the repeated use of the same data for three separate tests (i.e., only female sailors, only male sailors, and the entire community) within each community, an adjustment for multiple pairwise comparisons was necessary. When multiple pairwise comparisons are made using the same data, the rate of false positives

increases [5, 8]. In our research, a false positive constitutes a scenario in which we incorrectly claim to have detected an increase in the average sea tour length following the new policy. A false positive is problematic in this situation because it allows us to conclude that the new policy was effective in increasing the average length of sea tour when, in fact, it was ineffective at doing so. To account for the inflated rate of false positive results due to multiple comparisons, a Bonferroni correction was applied. The Bonferroni correction is an adjustment made to p-values to reduce the rate of false positives [6, 8]. The adjustment is computationally simple: the conventional significance level of 0.05 is divided by the number of multiple comparisons considered in the study. Consequently, rather than comparing p-values to the conventional 0.05 level, the p-values associated with our t-tests were rejected at the 0.0167 level, or 0.05/3. In terms of our hypothesis, we assumed that the new policy effectively increased the average length of sea tour for communities in which the results of the comparisons had one-tailed p-values that were smaller than 0.0167.

The SSF policy encompasses data from 2007 through 2014, and the new policy was implemented in September 2011. However, sailors who were within 9 months of completing the current sea tour were allowed to be grandfathered; hence, the new policy was not enforced until May 2012. Accounting for grandfathering, the pre-policy data available for this analysis were from 2007 to May 2012, and the post-policy data available were from May 2012 to 2014. Due to the imbalance in the amount of pre- and post-policy data, there was some concern regarding unequal sample sizes between groups. Specifically, the pre-policy data span 5.5 years, from 2007 to mid-2012, and have a much larger sample size than the post-policy data. Although the t-test is robust to differences in group sample sizes, larger sample sizes are associated with having greater statistical power. Statistical power is the probability of correctly detecting significant differences between groups, and it is positively associated with sample size [7-8]. In most statistical testing situations, larger samples are preferred because they yield greater statistical power. However, very large sample sizes can make a hypothesis test too powerful and produce significant results that do not necessarily have practical implications [9]. To avoid overinflating statistical power, as well as to ensure the comparability of the pre- and post-policy implementation data and keep sample sizes approximately equal, we decided to define the “pre-policy implementation” timeframe as 2010 to May 2012. Doing this ensured that the pre- and post-policy data both comprised approximately 2.5 years of data.

In the next few pages, we see the results of these analyses for the selected EMCs.

Individual EMC analysis

Aviation Machinist's Mate (AD)

The results of the t-tests conducted for ADs are presented in Table 8. In 2011, a change from 42 to 48 months was implemented for the first and second sea tours for this community.

Results show a significant increase in the average length of the first sea tour for the entire community. Before the implementation of the policy, the average length of the first sea tour was 35 months. Following the policy, the average length of the first sea tour increased to 38.4 months. In addition, the results of the subgroup analysis show that, after the policy implementation, the average length of the first sea tour increased within each gender group.

Although the policy was effective in increasing the amount of time spent on the first sea tour, the average time of the first sea tour did not approach the prescribed levels of either pre-policy change (35.0 months observed vs. prescribed 42 months) or post-policy change (38.4 months observed vs. prescribed 48 months).

There were no significant differences between the average time spent on sea tour before and after the policy implementation for the second tour. Similar to the situation observed in the first sea tour, the actual average amount of time spent on tour was below the prescribed sea tour length.

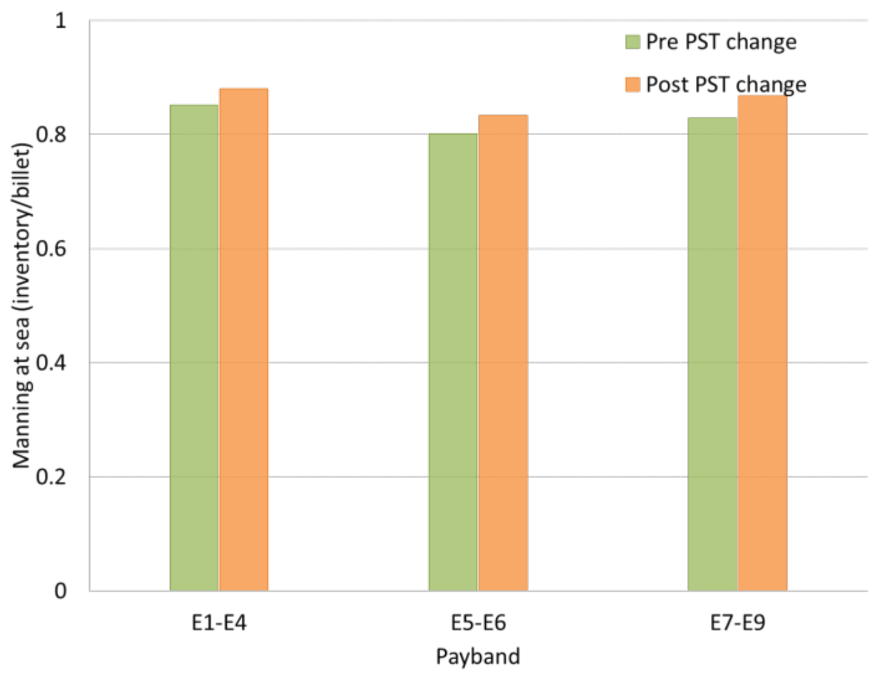
Overall, men completed longer tours than women for sea tours 1, 2, and 3. On the contrary, the results show that women completed longer sea tours than men during the fourth tour; however, these results are based on the average length of tour of less than 10 female sailors. Thus, it is difficult to generalize this finding to a larger population of female aviation machinist's mates.

Feeding the Navy's data on sea tour length into the DES-SSF model, we get the manning results consistent with insignificant increase in sea tour length as shown in Figure 18. Even though the first and second sea tours changed by more than 14 percent, the actual sea manning only increased by 4 percent at most. Note that in all figures in this appendix (Figure 18 through Figure 26) we only feed DES-SSF with sea and shore tour lengths for stayers (we exclude the losses) because the model independently calculates attrition time for each sailor.

Table 8. Average sea tour months per sailor: Aviation Machinist's Mate

ALL	Pre	Post	Significance level
First Tour			
All	**35.0 (N=1,280)**	**38.4 (N=1,239)**	**P < 0.0001**
Female	**29.3 (N=211)**	**33.8 (N=204)**	**P = 0.0008**
Male	**36.2 (N=1,069)**	**39.3 (N=1,035)**	**P < 0.0001**
Second Tour			
All	35.2 (N=549)	36.0 (N=420)	P = 0.1575
Female	27.2 (N=55)	27.1 (N=45)	P = 0.5042
Male	36.1 (N=494)	37.1 (N=375)	P = 0.1092
	No Change		
Third Tour			
All	35.2 (N=475)		
Female	30.4 (N=40)		
Male	35.7 (N=435)		
Fourth Tour			
All	31.7 (N=115)		
Female	37.8 (N=5)		
Male	31.4 (N=110)		

Figure 18. Impact of PST change on sea manning on ADs' sea manning



Damage Controlman (DC)

The results of the t-tests conducted for the Damage Controlman (DC) community are presented in Table 9. In 2011, a change from 54 to 60 months was implemented for the first and second sea tours, and a change from 36 to 48 months was implemented for the fourth sea tour. Based on the results, there was no significant increase in the average amount of time spent on tour for any of the sea tours.

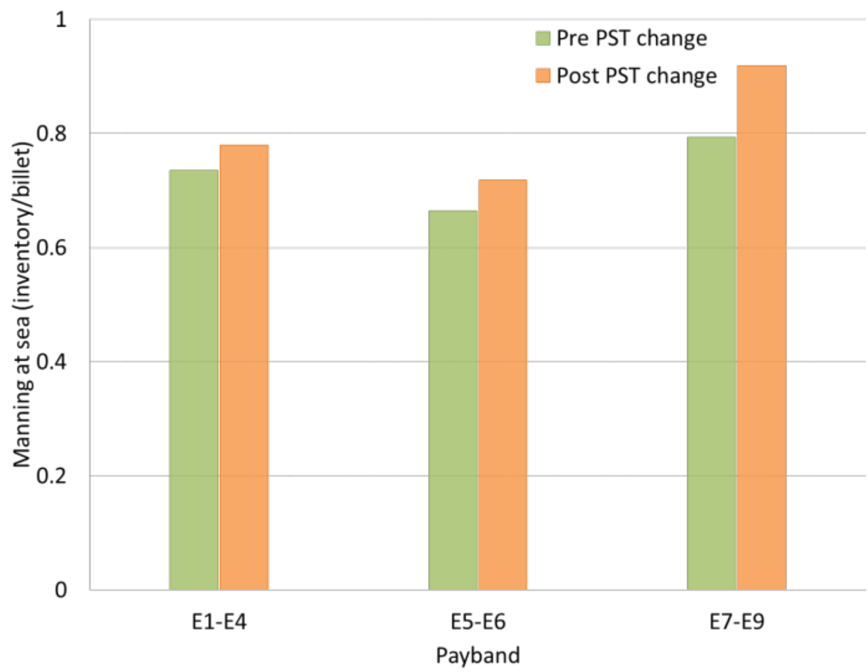
As observed in the AD community, the average time of the tours did not approach the prescribed levels—neither pre-policy change nor post-policy change. Figure 19 shows this trend. In some situations, such as for female DCs serving their second tour, the average length of sea tour was more than 30 months short of the prescribed 54-month pre-policy implementation, and the average length of sea tour was about a third of the prescribed 60-month post-policy implementation.

Overall, men completed longer tours than women for sea tours 1, 2, and 3. Women completed longer sea tours than men during the fourth tour before the policy implementation; however, these results are based on the average length of tour of less than five female sailors. It is difficult to generalize this finding to a larger population of female DCs.

Table 9. Average sea tour months per sailor: Damage Controlman

ALL	Pre	Post	Significance level
First Tour			
All	37.9 (N=738)	38.5 (N=612)	P = 0.2361
Female	28.5 (N=186)	31.6 (N=158)	P = 0.0338
Male	41.1 (N=552)	40.9 (N=454)	P = 0.6009
Second Tour			
All	34.3 (N=174)	32.2 (N=118)	P = 0.8648
Female	22.2 (N=39)	20.8 (N=40)	P = 0.6774
Male	37.9 (N=135)	38.1 (N=78)	P = 0.4520
Fourth Tour			
All	26.9 (N=27)	29.8 (N=29)	P = 0.1815
	No Change		
Third Tour			
All	34.5 (N=249)		
Female	26.4 (N=18)		
Male	35.1 (N=231)		

Figure 19. Impact of PST change on sea manning on DCs' sea manning



Submarine Sonar Technician (STS)

The results of the t-test conducted for the Submarine Sonar Technician (STS) community are presented in Table 10. In 2011, a change from 36 to 48 months was implemented for the second sea tour, and a change from 36 to 42 months was implemented for the third and fourth sea tours. The entire sample for this community consists of data from men.

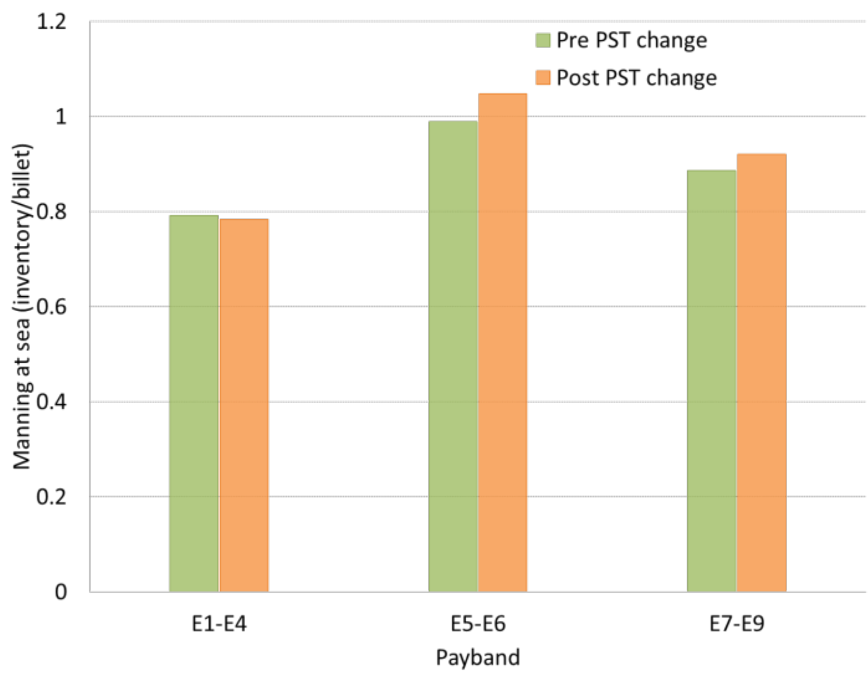
The policy change was effective in significantly increasing the amount of time spent on the second sea tour from an average of 37.5 to 41.4 months. Unlike the situation observed with the AD and DC communities, the observed average time spent at sea pre-policy exceeded the prescribed sea tour of 36 months for the second sea tour. However, the average time spent at sea after the implementation of the policy fell short of the prescribed 48 months. Similarly, the overall increase of sea manning as shown in Figure 20 is not significant, but it seems that the manning issue at sea for E5-E6 has been resolved completely by achieving a 100-percent fill rate.

No significant increase was examined pre- to post-policy change for sea tours 3 or 4. The average time spent at sea was below the notional 36 months pre-policy and 42 months post-policy for both sea tours.

Table 10. Average sea tour months per sailor: Sonar Technician, Submarine

ALL	Pre	Post	Significance level
Second Tour			
All (male)	**37.5 (N=149)**	**41.4 (N=92)**	**P = 0.0134**
Third Tour			
All (male)	35.0 (N=70)	35.2 (N=56)	P = 0.4657
Fourth Tour			
All (male)	25.1 (N=8)	29.4 (N=5)	P = 0.3001
	No Change		
First Tour			
All (male)	35.1 (N=126)		

Figure 20. Impact of PST change on sea manning on STSs' sea manning



Submarine Logistics Specialist (LSSS)

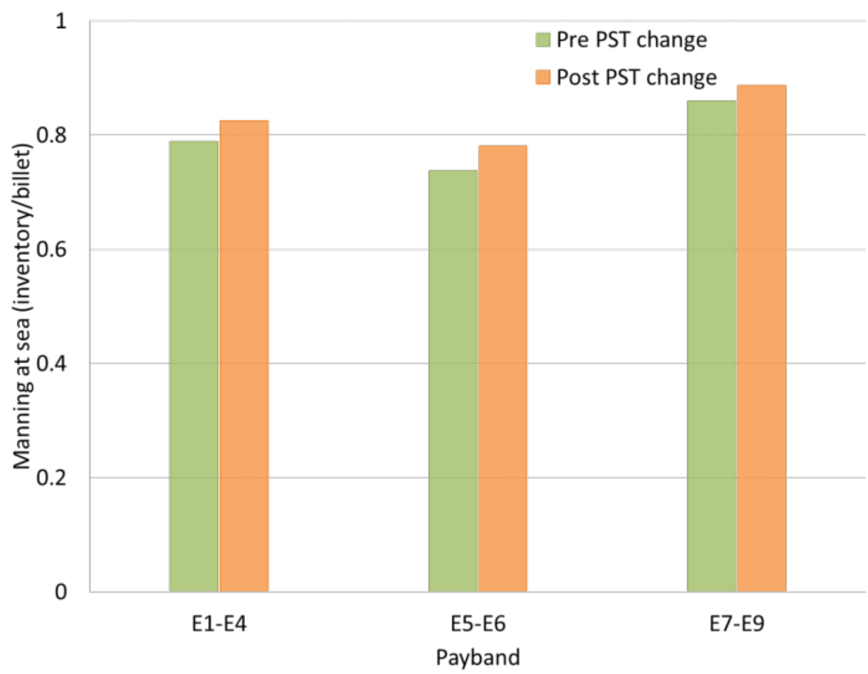
The results of the t-test conducted for the Submarine Logistics Specialist (LSSS) community are presented in Table 11. In 2011, a change from 36 to 48 months was implemented for the first sea tour, and a change from 36 to 42 months was implemented for the second sea tour. The entire sample for this community consists of data from men. Results suggest that the policy change did not stimulate any significant increase in the average time spent on sea tours or in sea manning (as shown in Figure 21). However, the average number of months spent on sea tours pre-policy change was close to the prescribed 36 months for tours 1, 2, and 3. The

post-policy averages fell short of the prescribed 48 and 42 months for sea tour 1 and 2, respectively.

Table 11. Average sea tour months per sailor: Logistics Specialist, Submarine

ALL	Pre	Post	Significance level
First Tour			
All (male)	36.5 (N=109)	38.0 (N=70)	P = 0.2554
Second Tour			
All (male)	35.8 (N=27)	37.3 (N=32)	P = 0.3056
	No Change		
Third Tour			
All (male)	37.3 (N=41)		
Fourth Tour			
All (male)	32.5 (N=18)		

Figure 21. Impact of PST change on sea manning on LSSSs' sea manning



Fire Control Technicians (FT)

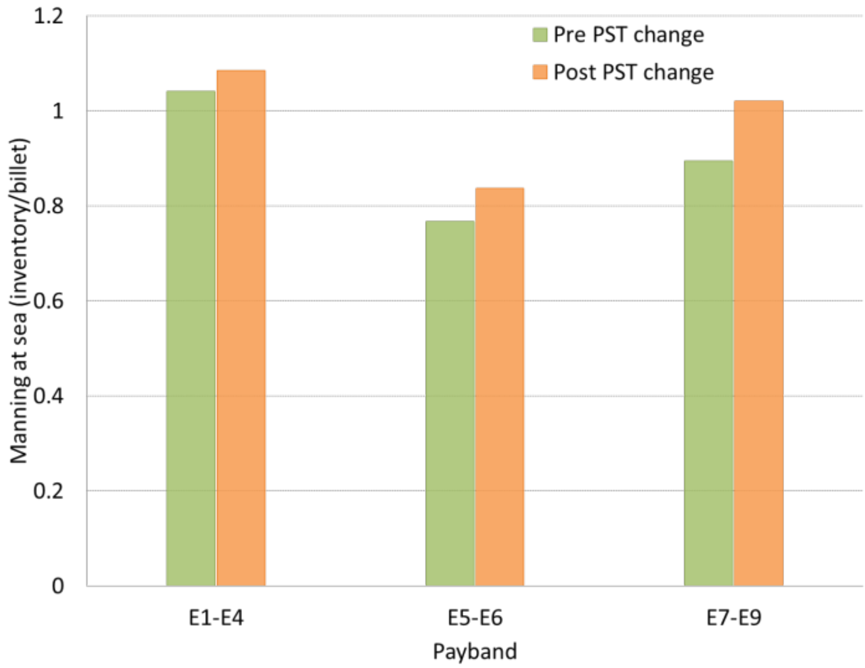
The results of the t-test conducted for FTs are presented in Table 12. In 2011, the following changes were implemented: from 48 to 54 months for the first sea tour, from 42 to 54 months for the second sea tour, from 36 to 48 months for the third sea tour, and from 36 to 42 months for the fourth sea tour. The entire sample for this community consists of data from men; no data were available for female FTs.

Results suggest that the policy change did not stimulate any significant increase in the average time spent on sea tours. However, the average number of months spent on sea tours pre-policy change was close to the prescribed 42 and 36 months for tours 2 and 3, respectively. The observed averages were approximately 8 and 15 months shorter pre-policy compared with the prescribed 48 and 36 months for tours 1 and 4, respectively. The data for tour 4 is not presented in Table 12 because of small sample sizes. The post-policy averages fell short of the prescribed length of tours for all sea tours. Sea manning did not increase significantly as a result of PST change. In Figure 22, a relatively large increase in E7-E9 sea manning can be observed; however, it's difficult to conclude any definite patterns because of a very small sample size.

Table 12. Average sea tour months per sailor: Fire Technician

ALL	Pre	Post	Significance level
First Tour			
All (male)	39.7 (N=313)	41.1 (N=267)	P = 0.1418
Second Tour			
All (male)	42.2 (N=77)	43.4 (N=40)	P = 0.3324
Third Tour			
All (male)	38.1 (N=39)	37.3 (N=22)	P = 0.5963

Figure 22. Impact of PST change on sea manning on FTs' sea manning



Culinary Specialist (CS)

The results of the t-test conducted for CSs are presented in Table 13. In 2011, a change from 48 to 54 months was implemented for the first and second sea tours. Although a notable discrepancy exists in the number of female and male CSs, more female sailors are represented in this community than in many other communities.

Based on the results of the t-tests for the second sea tour, there was a significant increase in the amount of time spent at sea post-policy for female CSs. This effect is masked by the disparity in sample sizes of the gender subgroups; hence, no significant policy effect is detected for the community when the gender covariate is ignored. On average, the new policy is associated with a 4.5-month increase in the second sea tour for female CSs (sea manning results shown in Figure 23 are consistent with these results).

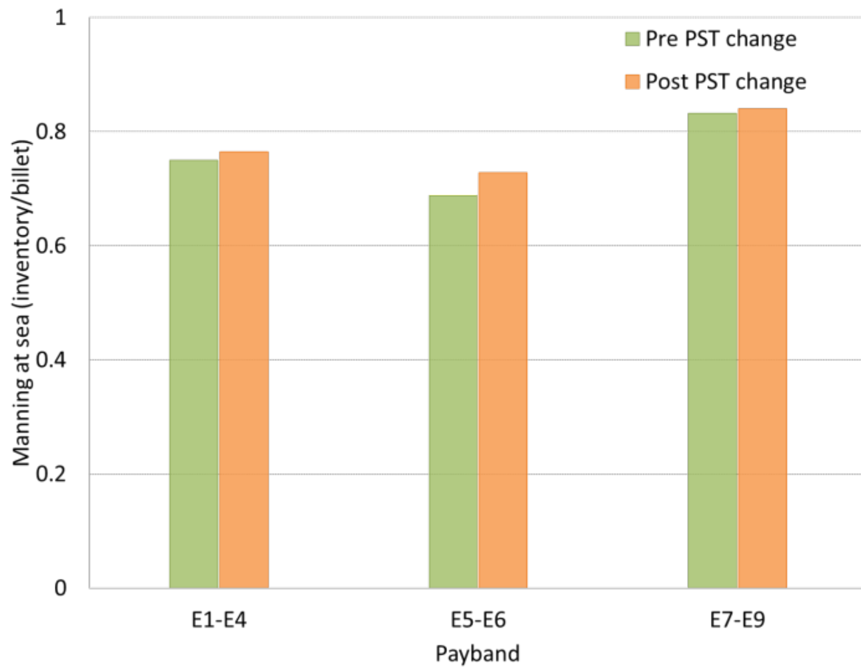
No significant increase in average sea tour length was observed for the first sea tour. The prescribed length of sea tours was not achieved pre-policy or post-policy implementation (48 and 54 months, respectively) during any of the sea tours.

Overall, male CSs completed longer tours than female CSs for all tours examined.

Table 13. Average sea tour months per sailor: Culinary Specialist

ALL	Pre	Post	Significance level
First Tour			
All	35.9 (N=1,924)	32.9 (N=1,220)	P = 0.9999
Female	29.0 (N=431)	27.3 (N=329)	P = 0.9389
Male	37.9 (N=1,493)	35.0 (N=891)	P = 0.9999
Second Tour			
All	31.5 (N=411)	33.0 (N=362)	P = 0.0872
Female	**23.2 (N=154)**	**27.7 (N=149)**	**P = 0.0034**
Male	36.5 (N=257)	36.8 (N=213)	P = 0.4246
	No Change		
Third Tour			
All	33.2 (N=673)		
Female	28.8 (N=114)		
Male	34.1 (N=559)		
Fourth Tour			
All	27.7 (N=193)		
Female	27.1 (N=44)		
Male	27.9 (N=149)		

Figure 23. Impact of PST change on sea manning on CSs' sea manning



Sonar Technician, Surface (STG)

The results of the t-test conducted for the STG community are presented in Table 14. In 2011, a change from 36 to 54 months was implemented for the second sea tour; a change from 36 to 48 months was implemented for the third sea tour.

No significant differences between the time spent on tour pre- and post-policy implementation were observed for any of the sea tours. The prescribed duration of 36 months was not met in sea tours 2 or 3 before the new policy. Moreover, the average number of months spent in the second sea tour post-policy was less than the pre-policy averages. As Figure 24 shows, sea manning did not increase significantly.

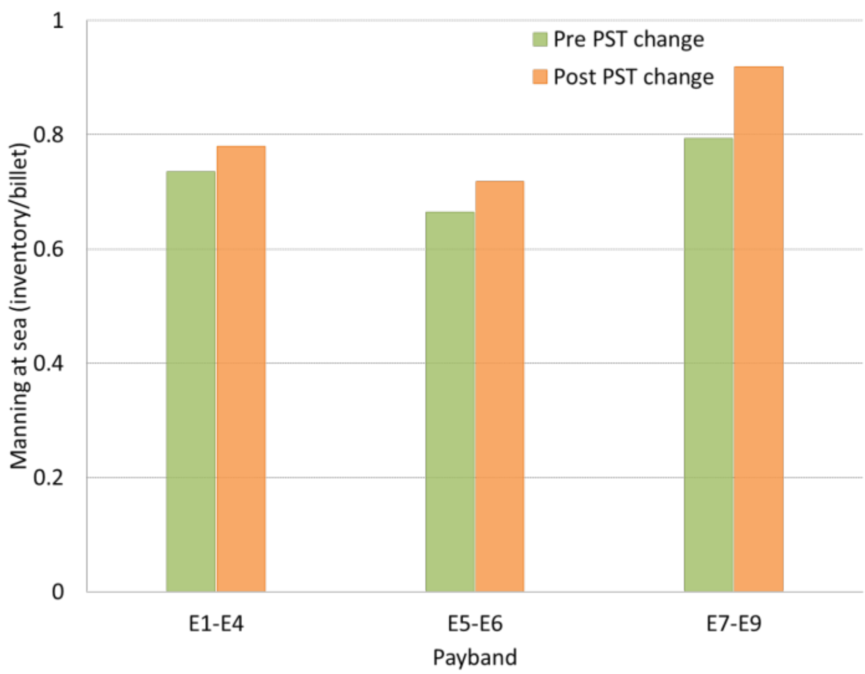
In the first sea tour, about 25 percent of STGs were female. This proportion dwindled to less than 13 percent in the second sea tour and even smaller, to approximately 5 percent and 8 percent, by the third and fourth sea tours, respectively.

On average, men completed longer sea tours than women for tours 1, 2, and 3. Although the average sea tour length of women was greater than that of men in the fourth sea tour, it is not practical to generalize this finding to a larger population of STGs, based on a sample size of less than five women.

Table 14. Average sea tour months per sailor: Sonar Technician, Surface

ALL	Pre	Post	Significance level
Second Tour			
All	33.8 (N=234)	31.3 (N=107)	P = 0.9692
Females	28.4 (N=30)	26.2 (N=20)	P = 0.7377
Male	34.5 (N=204)	32.4 (N=87)	P = 0.9315
Third Tour			
All	29.6 (N=87)	31.9 (N=88)	P = 0.0914
Females	25.8 (N=5)	33.4 (N=7)	P = 0.1447
Males	29.8 (N=82)	31.8 (N=81)	P = 0.1397
	No Change		
First Tour			
All	36.0 (N=1,080)		
Females	27.1 (N=266)		
Males	38.8 (N=814)		
Fourth Tour			
All	27.4 (N=24)		

Figure 24. Impact of PST change on sea manning on STGs' sea manning



Gunner's Mate (GM)

The results of the t-test conducted for the GM community are presented in Table 15. In 2011, the following changes were implemented: from 42 to 54 months for the first sea tour, from 36 to 54 months for the second sea tour, from 36 to 48 months for the third sea tour, and from 36 to 42 months for the fourth sea tour.

Based on the results of the t-tests for the first sea tour, there was a significant increase in the amount of time spent at sea post-policy for female GMs. Similar to the results of the analysis for CSs, this effect is masked by the disparity in sample sizes of the gender subgroups; hence, no significant policy effect is detected for the community when the gender covariate is ignored. On average, the new policy is associated with a 3-month increase in the second sea tour for female GMs.

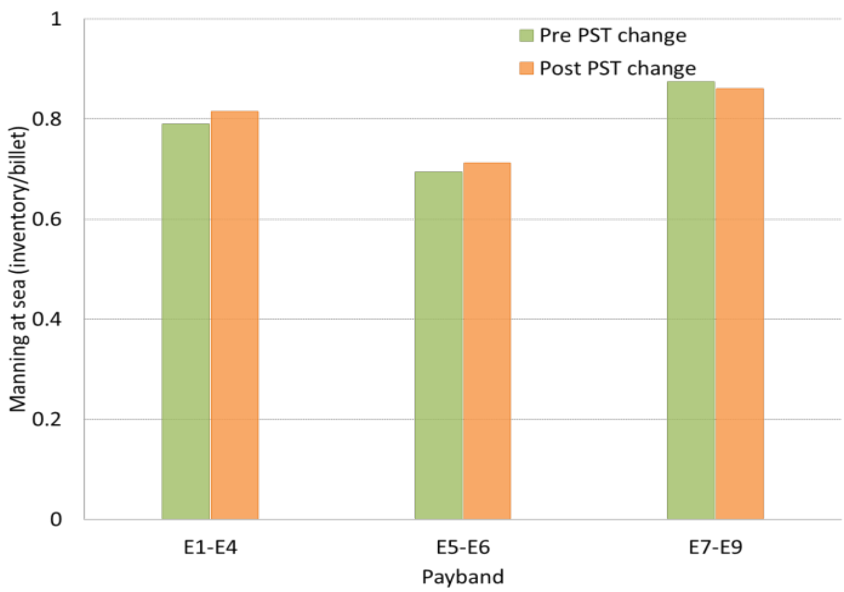
No significant increase in average sea tour length was observed for the second, third, or fourth sea tour. The prescribed sea tour length was not achieved before or after policy implementation during any of the sea tours. In addition, manning at sea did not change (see Figure 25).

Generally, male GMs completed longer tours than female GMs.

Table 15. Average sea tour months per sailor: Gunner's Mate

ALL	Pre	Post	Significance level
First Tour			
All	33.6 (N=932)	32.8 (N=842)	P = 0.9287
Female	**24.2 (N=163)**	**27.3 (N=210)**	**P = 0.0120**
Male	35.6 (N=769)	34.6 (N=632)	P = 0.9546
Second Tour			
All	32.0 (N=301)	31.8 (N=158)	P = 0.5757
Female	24.1 (N=44)	27.2 (N=39)	P = 0.1720
Male	33.4 (N=257)	33.3 (N=119)	P = 0.5288
Third Tour			
All	31.4 (N=130)	32.3 (N=126)	P = 0.2783
Female	21.1 (N=7)	28.9 (N=10)	P = 0.1551
Male	32.0 (N=123)	32.6 (N=116)	P = 0.3485
Fourth Tour			
All	25.4 (N=35)	26.4 (N=31)	P = 0.3560

Figure 25. Impact of PST change on sea manning on GMs' sea manning



Machinery Repair (MR)

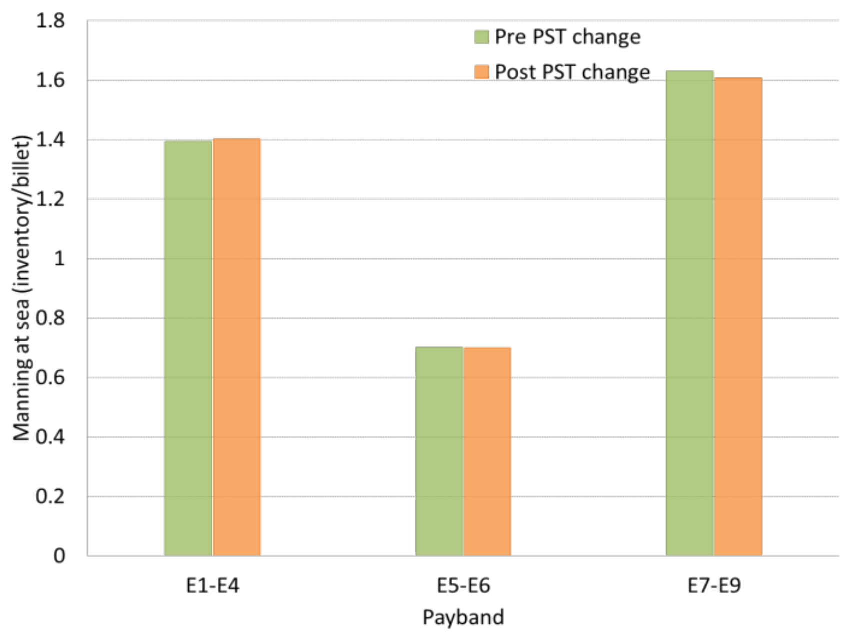
The results of the t-test conducted for the MR community are presented in Table 16. In 2011, a change from 36 to 42 months was implemented for the second sea tour. No significant increase in the average time spent at sea was observed. As a result, sea manning also did not improve (see Figure 26).

Approximately 30 percent of MRs were women during the first sea tour, and fewer female MRs completed subsequent sea tours.

Table 16. Average sea tour months per sailor: Machinery Repair

ALL	Pre	Post	Significance level
Second Tour			
All	33.7 (N=59)	34.1 (N=28)	P = 0.4405
Female	24.4 (N=5)	14.4 (N=5)	P = 0.9061
Male	34.5 (N=54)	38.4 (N=23)	P = 0.0957
	No Change		
First Tour			
All	35.5 (N=259)		
Female	26.0 (N=76)		
Male	39.4 (N=183)		
Third Tour			
All	35.4 (N=59)		
Fourth Tour			
All (male)	30.2 (N=17)		

Figure 26. Impact of PST change on sea manning on MRs' sea manning



Conclusions

Overall, the results of our analyses suggest that the policy was not very effective in increasing the average length of sea tour for the majority of communities. Furthermore, in most communities, the observed average length of time spent in a given sea tour fell short of the prescribed sea tour duration. Although men tended to serve longer tours than women, even their observed averages often did not approach the prescribed pre- or post-policy change sea tour lengths.

Appendix B: Sea Manning

In this appendix, we present the result of sea manning under two policies:

- Comparing sea manning under the old and new PSTs (note that some of these results were presented in the body of the paper)
- Comparing sea manning under the old PST with a policy of shorter shore duty

Sea manning under the old and new PSTs

Damage Control (DC)

DC sailors do the work necessary for damage control, ship stability, firefighting, fire prevention, and chemical, biological, and radiological (CBR) warfare defense. DC is a surface mission area community in the surface engineering subcategory and is a sea-intensive rating with limited in-rating shore duty. DC sailors enter the Navy on a four-year contract with a required ASVAB line score (either VE+AR+MK+AS or VE+AR+MK+MC) of 205 and have an average STF time of 6.3 months. The DC community is currently overmanned at 102 percent, with sea and shore manning both over 100 percent [4]. This means the community has restricted opportunity for reenlistment, advancement, and conversion for PACT and RC sailors. The promotion opportunity is only above ALNAV percentages for the E7 category. The average DC will promote to E4 at 2 years of service and to E5 at 4.5 years of service. DC also has a large female sailor population that is expected to grow in the future, with 34 percent of all DC accessions being women in FY16. Table 17 shows the sea/shore flow for DCs.

Table 17. Damage Control (DC) sea/shore flow

Tour	1st	2nd	3rd	4th	5th	6th	7th
SEA_{old}	54	54	48	36	36	36	36
SEA_{new}	60	60	48	48	36	36	36
SHORE	36	36	36	36	36	36	36

The increase in first sea tour from 54 to 60 barely improves sea manning, as seen in Figure 27. This is mainly because the DCs are under a four-year contract with a continuation rate of less than 55 percent beyond their first enlistment contract. Their initial training combined with their first sea tour exceeds their four-year initial obligation, even under the old PST.

The change in PST has a positive effect on sea manning for both the E5-E6 and E7-E9 paybands (see Figure 28 and Figure 29). It is noteworthy that these effects are not statistically significant based on our analysis using the t-test in Appendix A.

Figure 27. DCs' E1-E4 sea manning under the old and the new PST

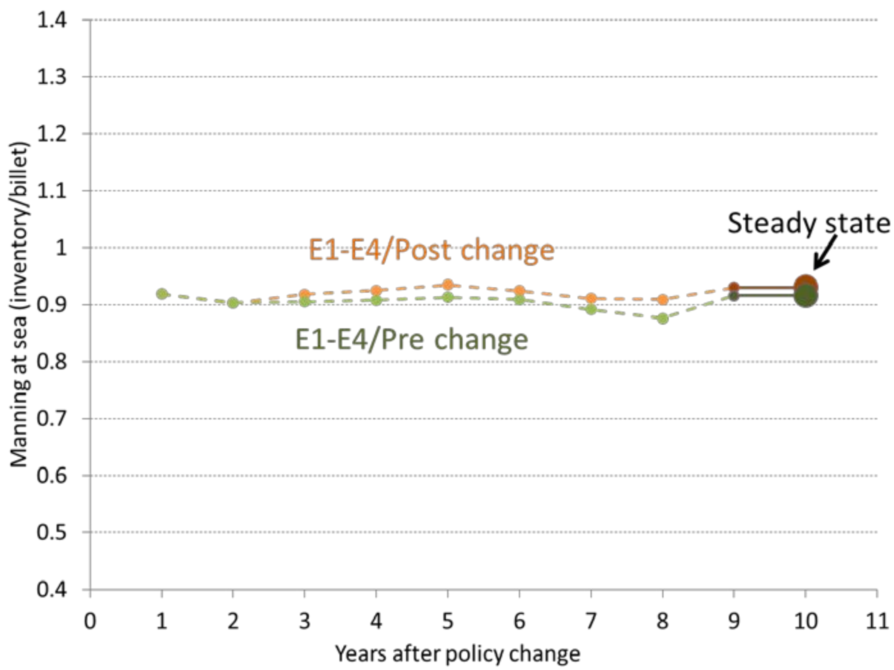


Figure 28. DCs' E5-E6 sea manning under the old and the new PST

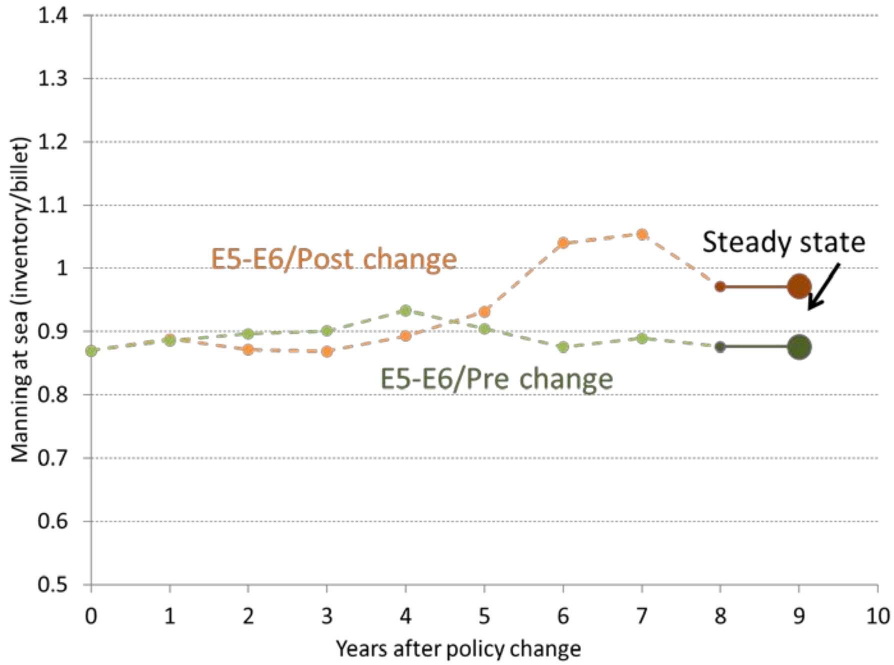
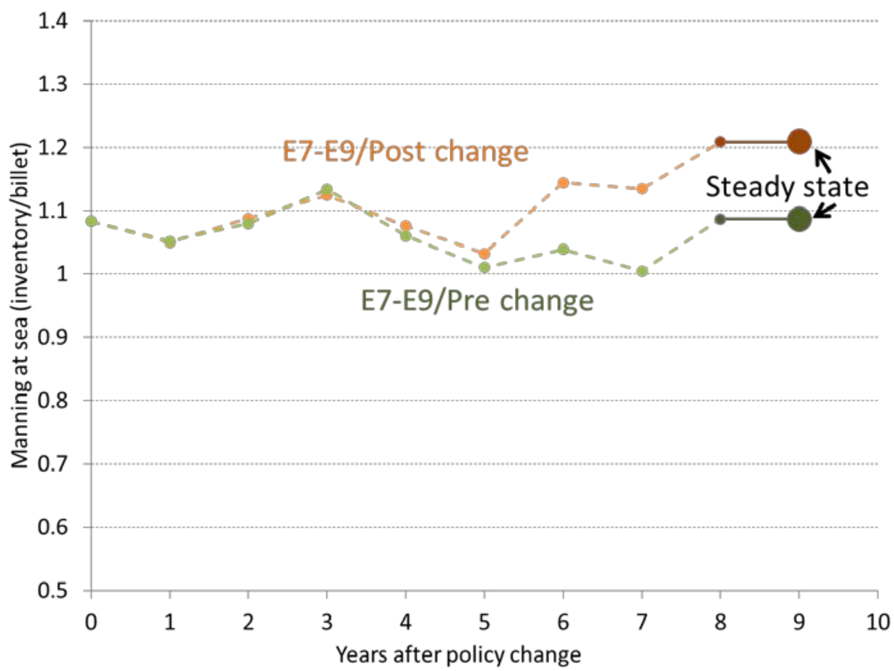


Figure 29. DCs' E7-E9 sea manning under the old and the new PST



The policy of decreasing the length of shore duty to 24 months to improve sea manning is not effective in improving sea manning for DCs since more than 97 percent of DC sailors start their initial duty at sea.

Fire Control Technicians (FT)

FTs receive extensive training in the operation and maintenance of advanced electronic equipment and computers used in submarine combat control and weapons systems. FTs require a 222 line score (AR+MK+EI+GS or VE+AR+MK+MC) on the ASVAB and enter the Navy under a six-year contract. They have an extensive initial training pipeline and an average STF time of 15.1 months. FT is considered a sea-centric community, with sea manning at 109 percent [4]. However, this high at-sea manning level is misleading because the majority of their inventory is at the E3 paygrade, with a manning surplus of 160 percent. At the same time, the FT community has significant at-sea shortages in the E4, E8, and E9 paygrades. The promotion opportunity for this community falls below the Navy percentages for the E4, E6 and E8, but is above the Navy percentages for the E5, E7 and E9 paygrades implying that there are fewer promotion quotas to the E4, E6, and E8 levels available for FTs, relative to the average promotion opportunity of the Navy at those paygrades. The average FT will promote to E4 at 3 years of service and to E5 at 4.3 years of service. Although all submarine communities will eventually open to women, there are no female accessions in the FY16 accession plan for this community. Because of the high ASVAB and training requirements, the FT is not a PACT-in community. Table 18 shows the sea/shore flow of FTs before and after the policy change.

Table 18. Fire Control Technician (FT) sea/shore flow

Tour	1st	2nd	3rd	4th	5th	6th	7th
SEA_{old}	48	42	36	36	36	36	36
SEA_{new}	54	54	48	42	36	36	36
SHORE	36	36	36	36	36	36	36

FTs had changes in all of the first four sea tours in September 2011. The changes resulted in an improvement in manning at sea across all paybands (see Figure 30 through Figure 32). We believe that one of the key factors contributing to this consistent improvement is the enhanced alignment between the length of the contract and the initial training with the first sea tour.

Figure 30. FTs' E1-E4 sea manning under the old and the new PST

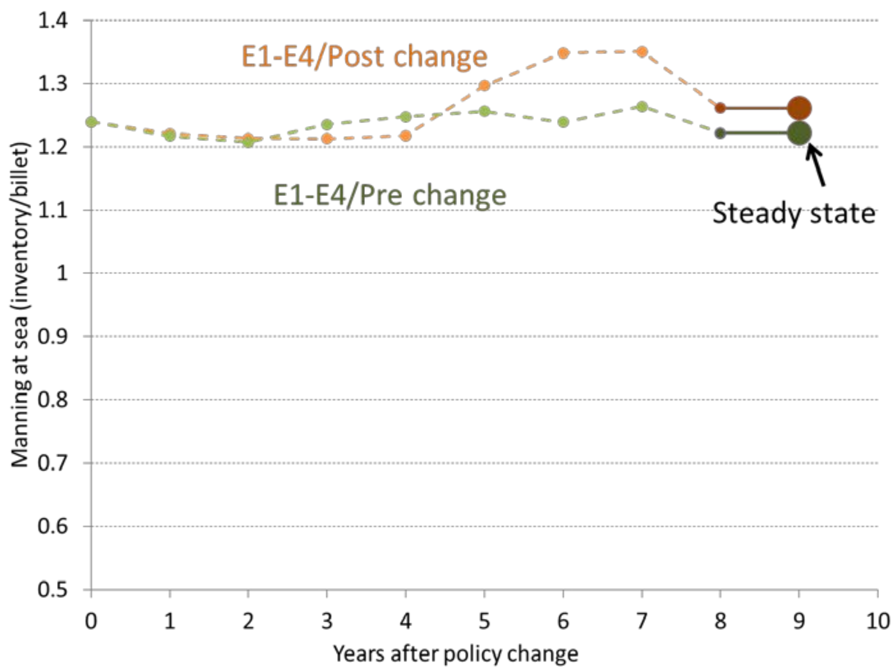


Figure 31. FTs' E5-E6 sea manning under the old and the new PST

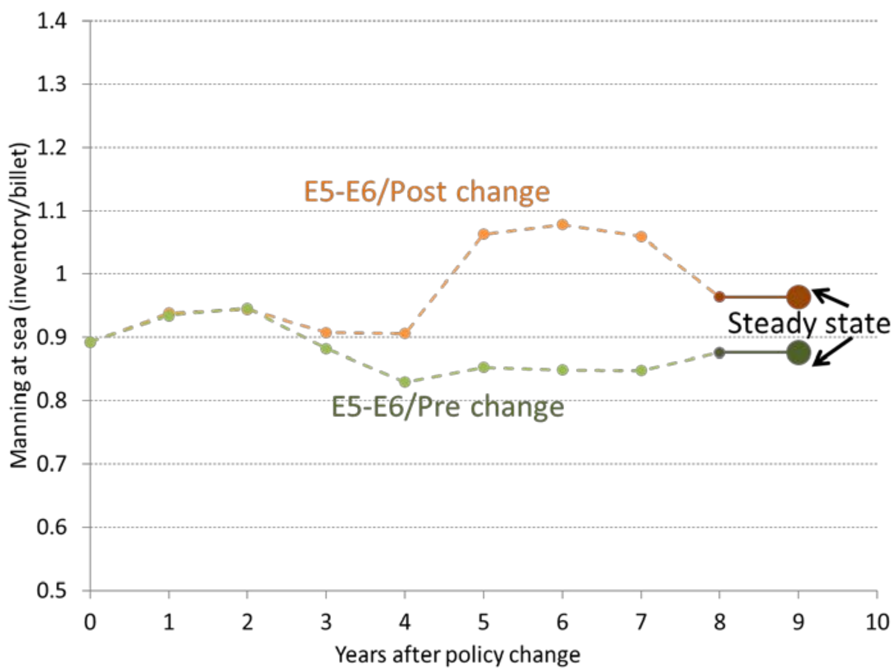
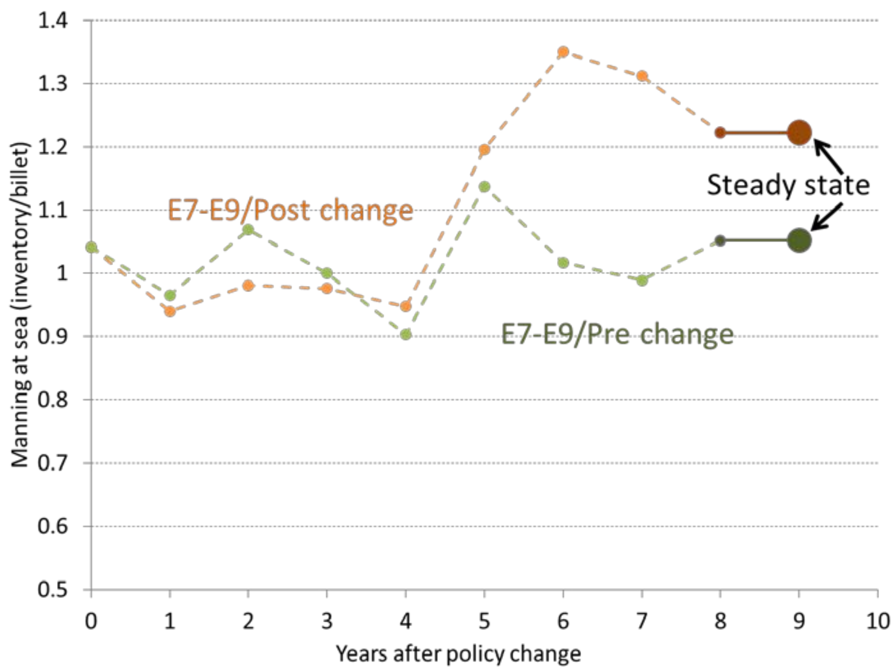


Figure 32. FTs' E7-E9 sea manning under the old and the new PST



Gunner's Mate (GM)

GMs are responsible for the operation and maintenance of guided-missile launching systems, gun mounts, and other ordnance equipment, as well as small arms and magazines. GM is a surface mission area community in the surface operations subcategory. It is considered a sea-centric community and has an average STF time of 11.3 months. GMs require an ASVAB line score (AR+MK+EI+GS) of 205 and a four-year contract. Current GM manning is at 93.8 percent, with sea manning lagging behind at 90 percent. The largest manning shortfalls are at paygrades E3 and below [4]. Promotion opportunity for GMs is well above the ALNAV percentages in all promotion categories, with the exception of the E6, E8, and E9 levels. The average GM will promote to E4 at 1.8 years of service and to E5 at 3.5 years of service. The female GM community is also expected to grow, with an FY 2016 female accession percentage of 30 percent. This community is considered open for PACT-in sailors. Table 19 shows the sea/shore flow of GMs before and after the policy change.

Table 19. Gunner's Mate (GM) sea/shore flow

Tour	1st	2nd	3rd	4th	5th	6th	7th
SEA_{old}	42	36	36	36	36	36	36
SEA_{new}	54	54	48	42	36	36	36
SHORE	36	36	36	36	36	36	36

The results of PST change for GMs are very similar in nature to those of the FTs. Benefits of increased PST of the first sea tour were greater for the FTs than for GMs, mainly because of the longer FT contract length of five years versus the GM contract of four years. The results are demonstrated in Figure 33 through Figure 35. We also tested the policy of shortened shore tour length to 24 months for the GM community using the DES-SSF. Our analysis confirmed that the increase in PST resulted in better sea manning and less harm to shore manning, compared with a policy with shortened shore tour (the results are presented later in this appendix).

Figure 33. GMs' E1-E4 sea manning under the old and the new PST

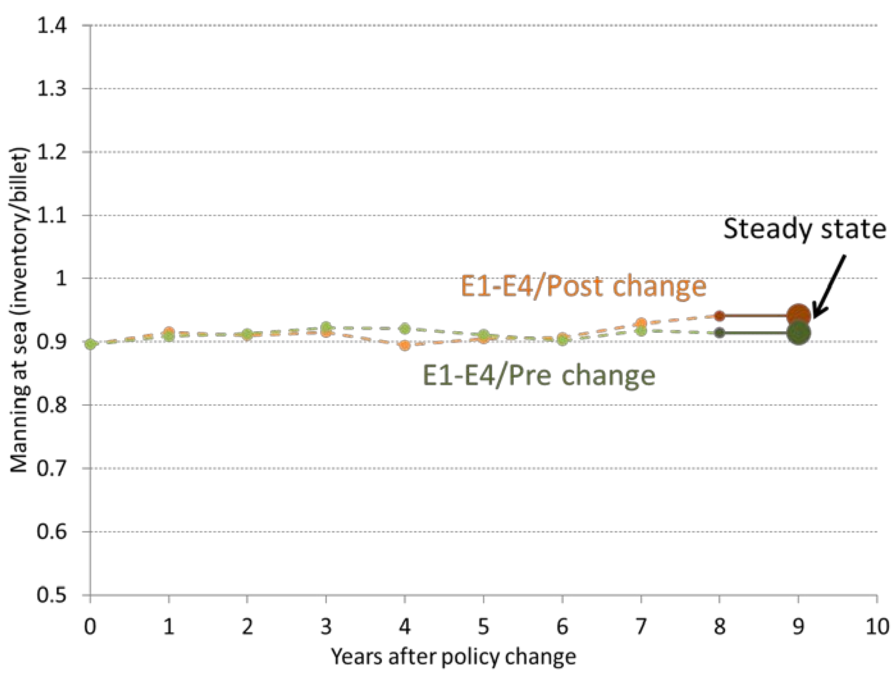


Figure 34. GMs' E5-E6 sea manning under the old and the new PST

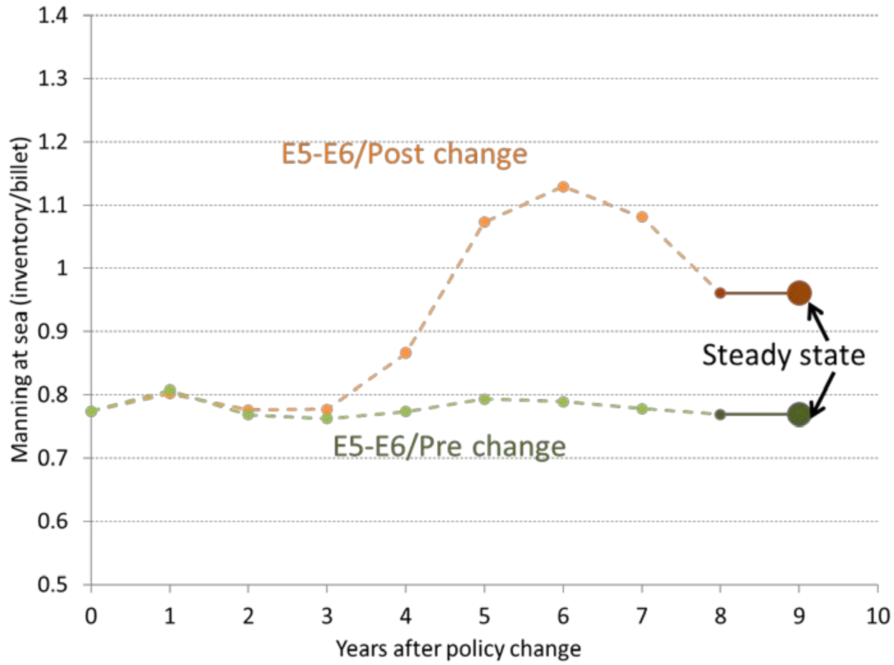
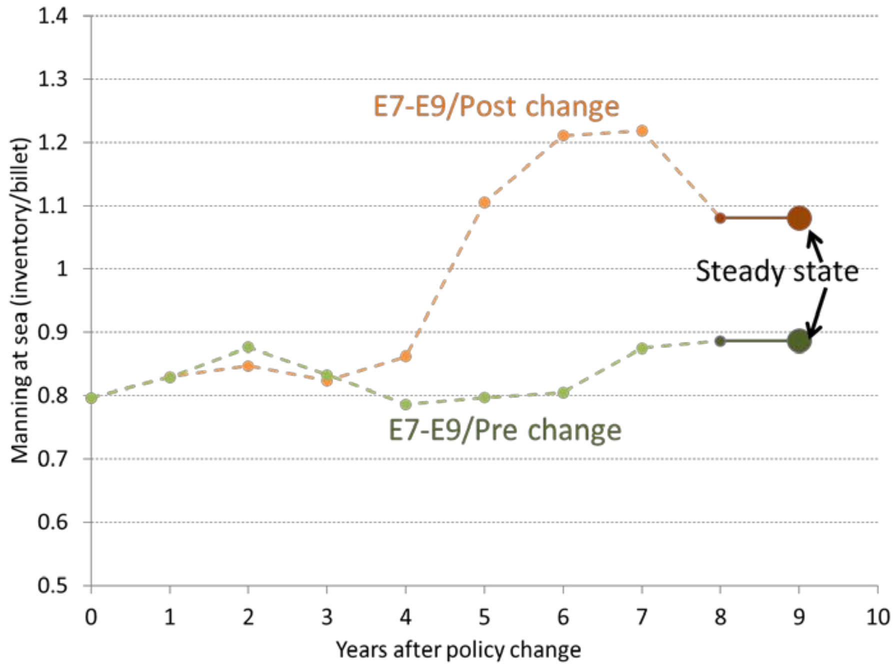


Figure 35. GMs' E7-E9 sea manning under the old and the new PST



Machinery Repairmen (MR)

MRs are skilled machine tool operators who make replacement parts and repair or overhaul engines and auxiliary systems of ships. MRs require an ASVAB line score (VE+AR+MK+AS or VE+AR+MK+MC) of 205 and enter the Navy on a four-year contract. The MR is a surface mission area in the surface engineering subcategory. It is a shore-centric community with an eight-month average STF time. The MR community is significantly overmanned at 116 percent, with sea manning at 128 percent [5]. A large cohort of sailors in levels E4 and below is a contributing factor to the overmanning. However, the promotion opportunity at the E4 and E5 levels remains above the ALNAV percentages. All other promotion categories lag behind the ALNAV percentages. The average MR will promote to E4 at 2.25 and to E5 at four years of service. The MR community will increase its female population with an accession goal of 30 percent in FY16. Although the MR is a PACT-in community, opportunity is limited because of overmanning. The sea/shore flow of MRs is shown in Table 20.

Table 20. Machinery Repairman (MR) sea/shore flow

Tour	1st	2nd	3rd	4th	5th	6th	7th
SEA_{old}	48	36	36	36	36	36	36
SEA_{new}	48	42	36	36	36	36	36
SHORE	36	36	36	36	36	36	36

MRs had one PST change during their second sea tour in September 2011. As a result, sea manning for the E1-E4 levels remains unchanged, but we observed an increase in sea manning for the E5-E6 and E7-E9 levels (see Figure 36 through Figure 38). A PST change results in greater improvements in sea manning, compared with shortened shore tours (see later in this appendix).

Figure 36. MRs' E1-E4 sea manning under the old and the new PST

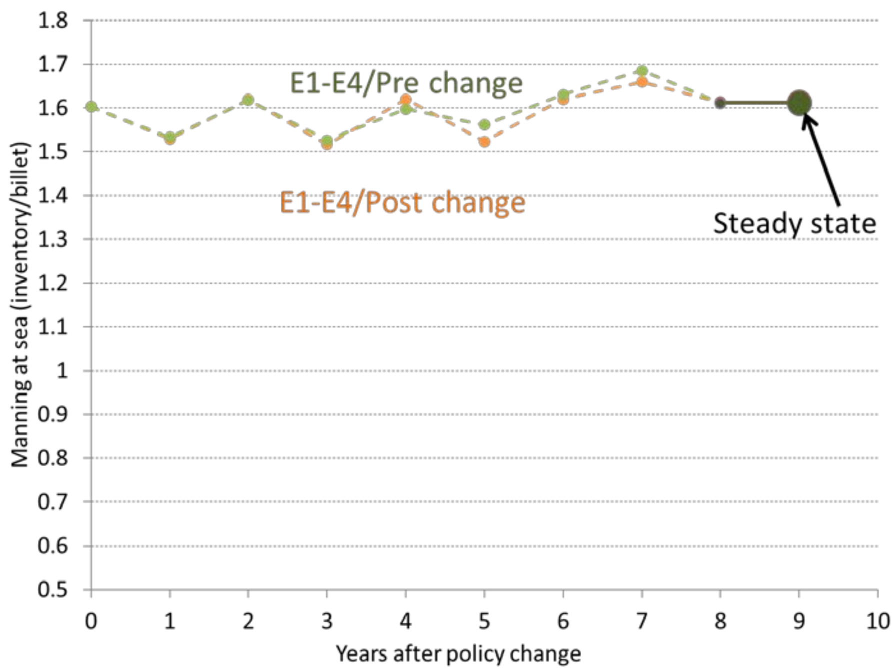


Figure 37. MRs' E5-E6 sea manning under the old and the new PST

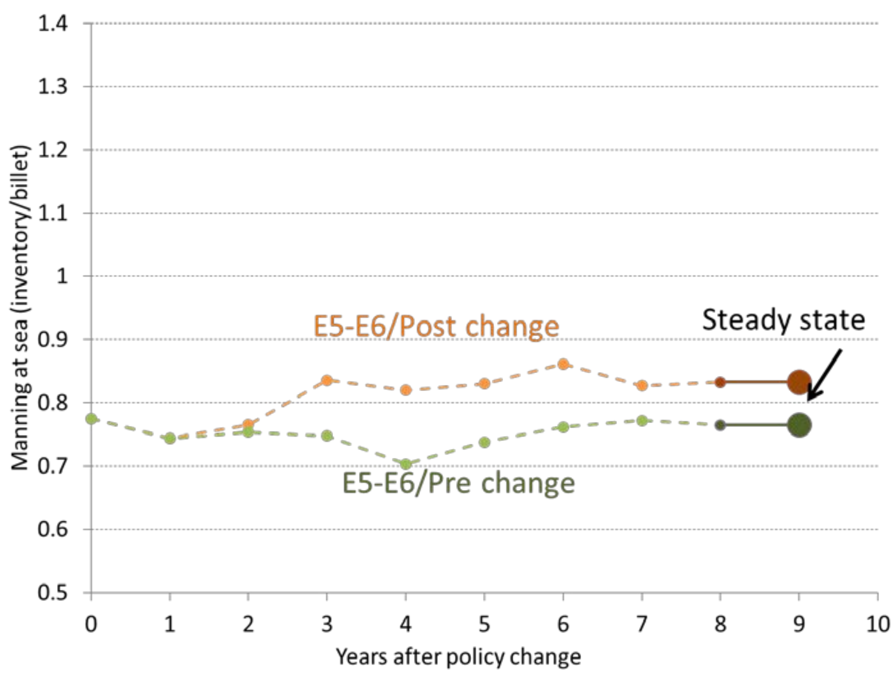
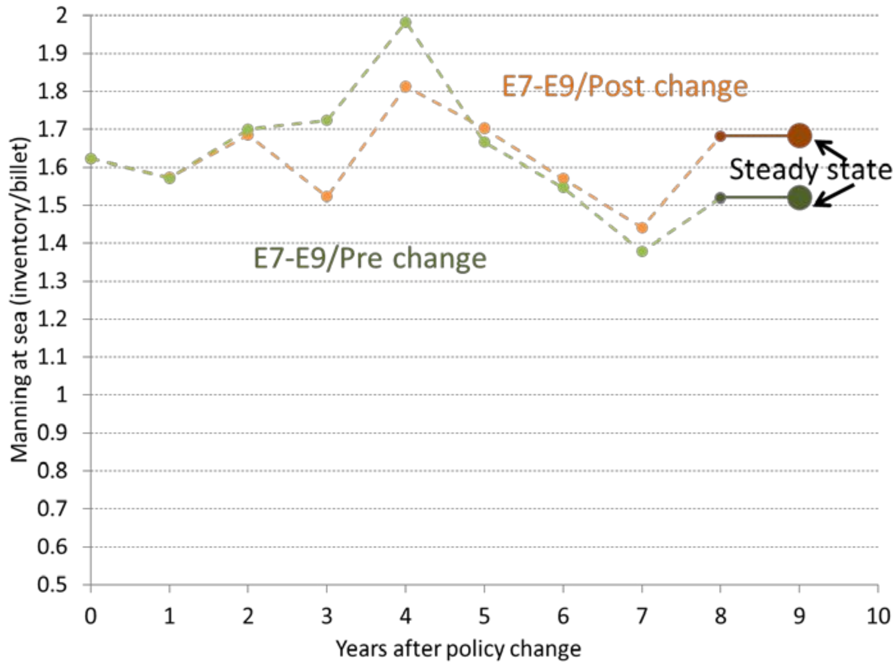


Figure 38. MRs' E7-E9 sea manning under the old and the new PST



Sonar Technician Surface (STG)

STGs are operators and electronics technicians who are responsible for keeping sonar systems and equipment in good operating condition on surface ships, such as frigates, minesweepers, destroyers, and cruisers, at remote locations throughout the world. The STG is a surface mission area community in the surface operations subcategory. STGs require an ASVAB line score (AR+MK+EI+GS) of 223 and enter the Navy on either a four- or six-year contract, depending on their chosen training pipeline. The STG is a sea-centric community with an average STF time of 15 months. STGs are undermanned at 95 percent, with at-sea manning slightly higher than shore manning. Promotion opportunity is above the ALNAV percentages with the exception of the E6 and E9 paygrades [5]. The average STG will promote to E4 at 1.6 years of service and to E5 at 3.6 years of service. The STG community is increasing its female population and has a female accession goal of 27 percent in FY 2016. It is not a PACT-in community. Table 21 shows the sea/shore flow of STGs.

Table 21. Sonar Technician Surface (STG) sea/shore flow

Tour	1st	2nd	3rd	4th	5th	6th	7th
SEA_{old}	54	36	36	36	36	36	36
SEA_{new}	54	54	48	36	36	36	36
SHORE	36	36	36	36	36	36	36

The PSTs of STGs were increased for the second and third sea tours. As a result, their E1-E4 sea manning remains relatively unchanged, but increases in E5-E6 and E7-E9 sea manning are observed (see Figure 39 through Figure 41). The policy of shortened shore duty seems to perform well for the E5-E6 STG sea manning, achieving almost 100 percent manning at sea for that payband (see Figure 42).

Figure 39. STGs' E1-E4 sea manning under the old and the new PST

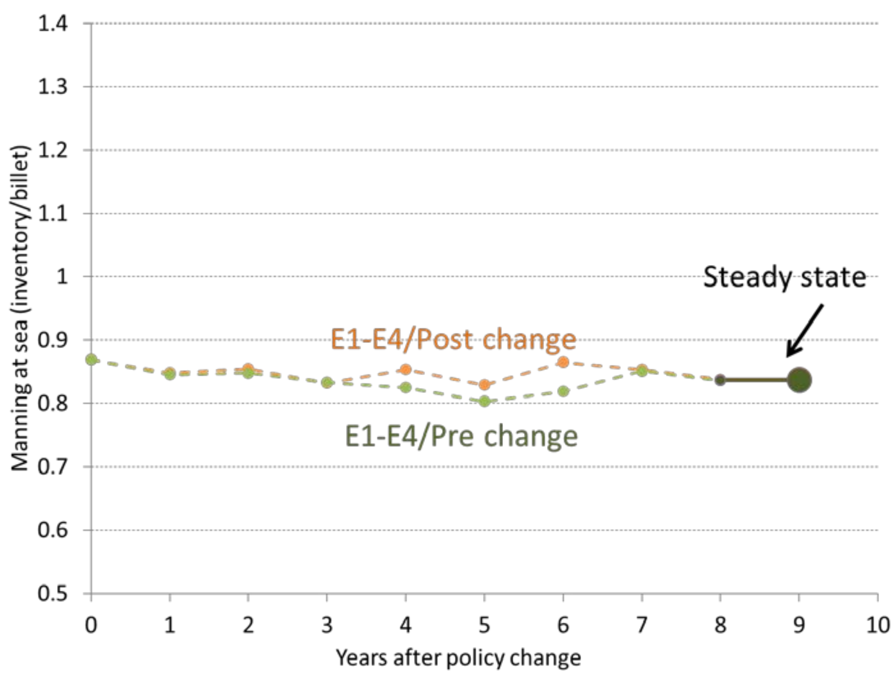


Figure 40. STGs' E5-E6 sea manning under the old and the new PST

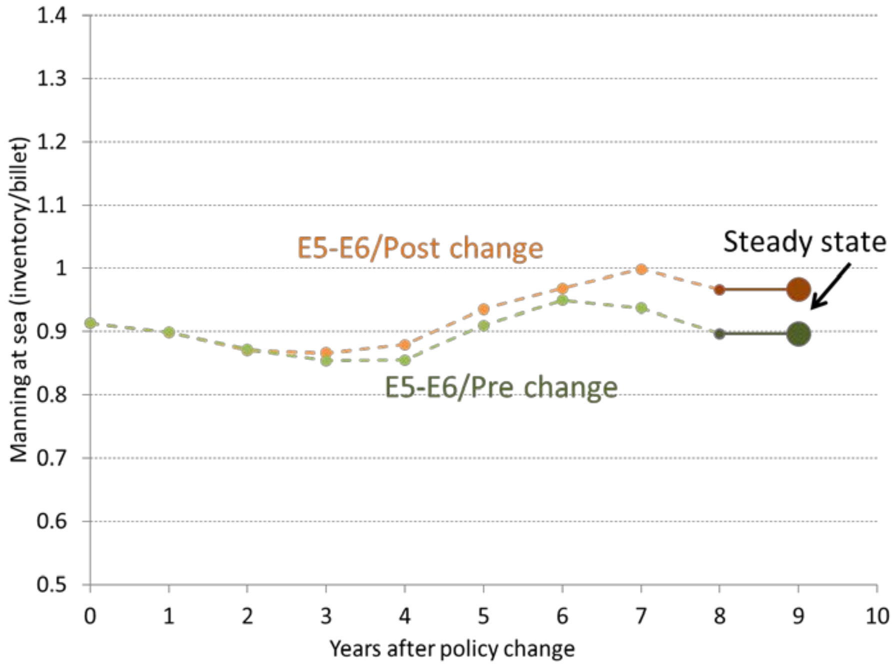


Figure 41. STGs' E7-E9 sea manning under the old and the new PST

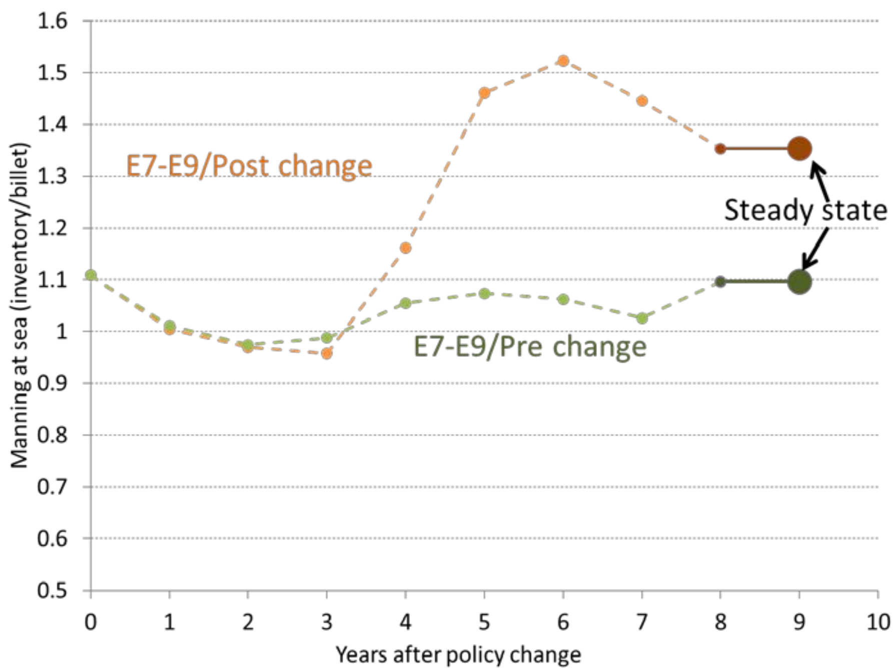
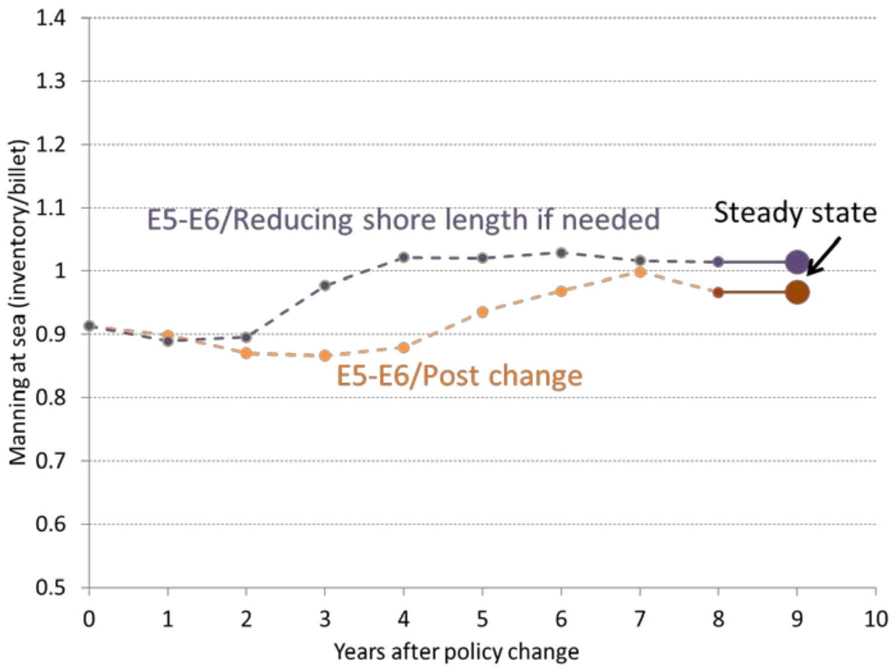


Figure 42. STGs' E5-E6 sea manning under the new PST vs. the shorter shore length policy



Sonar Technician Submarine (STS)

STS sailors receive extensive training in the operation and maintenance of advanced electronic equipment and computers used in sound, navigation, and ranging systems. STSs require a 222 ASVAB line score (AR+MK+EI+GS or VE+AR+MK+MC) and enter the Navy under a six-year contract. Because of their comprehensive initial training requirements, they have an average STF time of 13.7 months. The average STS will promote to the E4 level at 2.6 years of service and to the E5 level at 4.6 years of service. The STS community is considered sea-centric and is currently manned at 105 percent at sea with an overall manning of 103 percent [4]. Promotion opportunity is below the ALNAV percentages, with the exception of a promotion to the E8 paygrade. Although all submarine communities will eventually open to women, there are no female accessions in the FY 2016 accession plan for this community. STS is not a PACT-in community, owing to the high ASVAB and training requirements. The sea/shore flow of STSs is shown in Table 22.

Table 22. Sonar Technician Submarine (STS) sea/shore flow

Tour	1st	2nd	3rd	4th	5th	6th	7th
SEA_{old}	48	36	36	36	36	36	36
SEA_{new}	48	48	42	42	36	36	36
SHORE	36	36	36	36	36	36	36

Sea manning of STSs increased for both the E5-E6 and E7-E9 paybands as a result of PST change. The pattern of change shown in the following figures is very similar to that seen in the STG community (see Figure 43 through Figure 45). However, shortened shore length does not seem to be as beneficial for STS sea manning (see later in this appendix).

Figure 43. STSs' E1-E4 sea manning under the old and the new PST

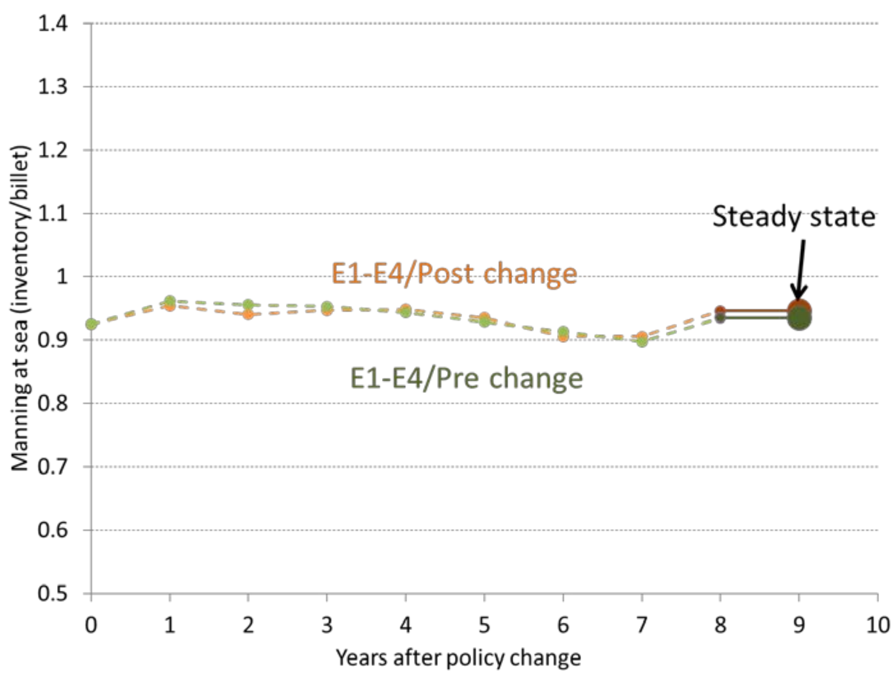


Figure 44. STSs' E5-E6 sea manning under the old and the new PST

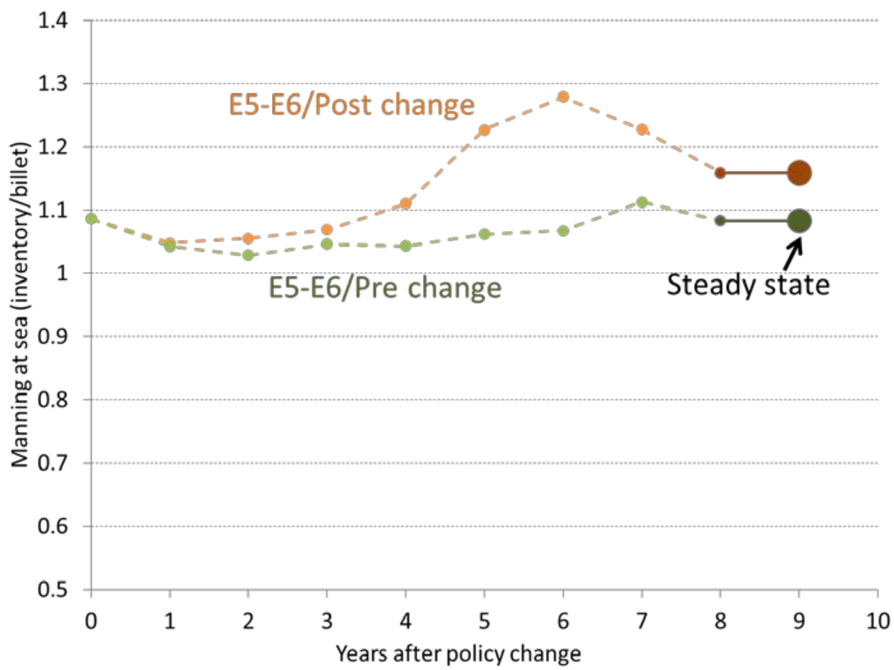
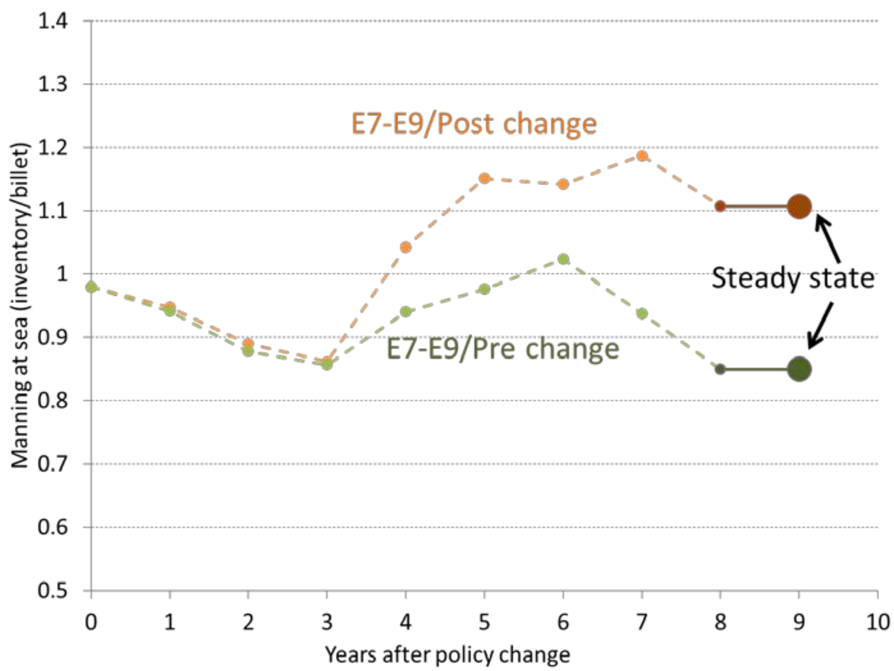


Figure 45. STSs' E7-E9 sea manning under the old and the new PST



Sea manning under the new PST compared with shorter shore policy

Culinary Specialist (CS)

Figure 46. CSs' E1-E4 sea manning under the new PST vs. the shorter shore length policy

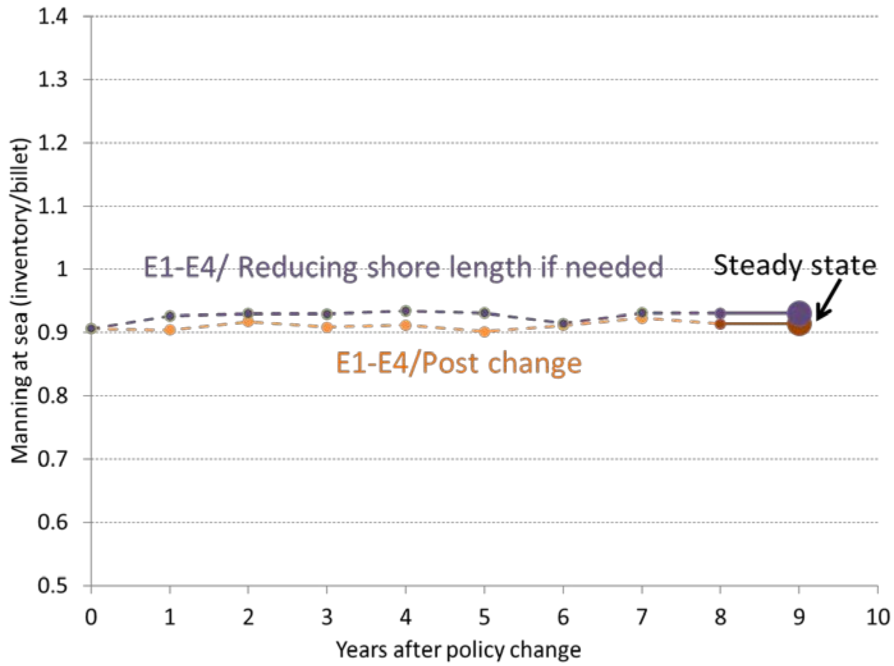


Figure 47. CSs' E5-E6 sea manning under the new PST vs. the shorter shore length policy

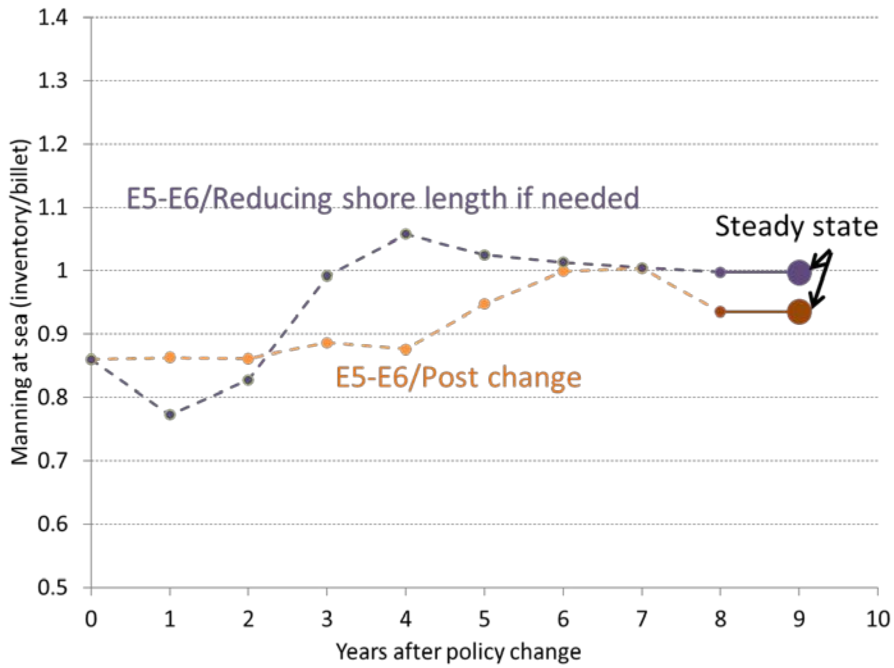
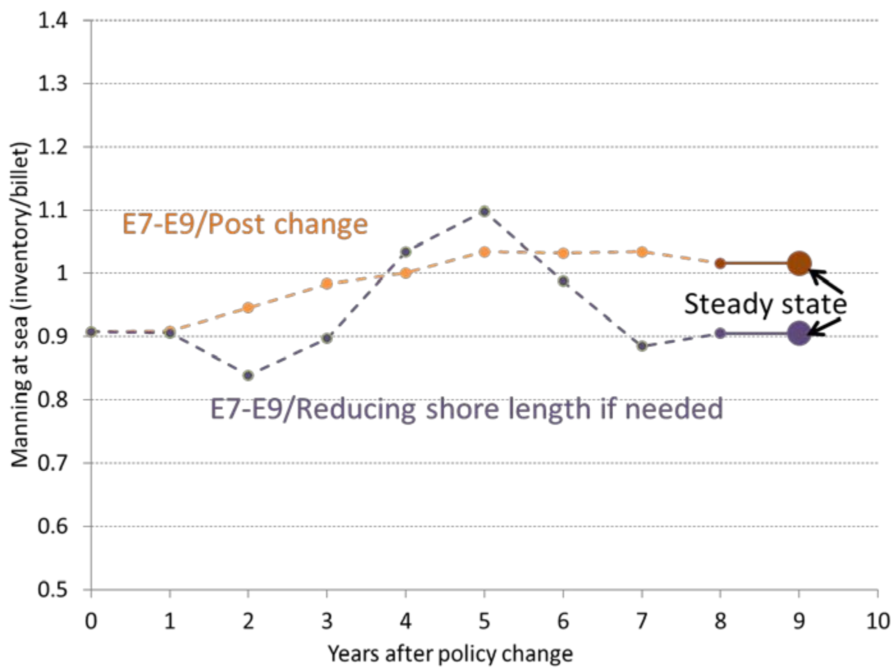


Figure 48. CSs' E7-E9 sea manning under the new PST vs. the shorter shore length policy



Damage Control (DC)

Figure 49. DCs' E1-E4 sea manning under new PST vs. shorter shore length policy

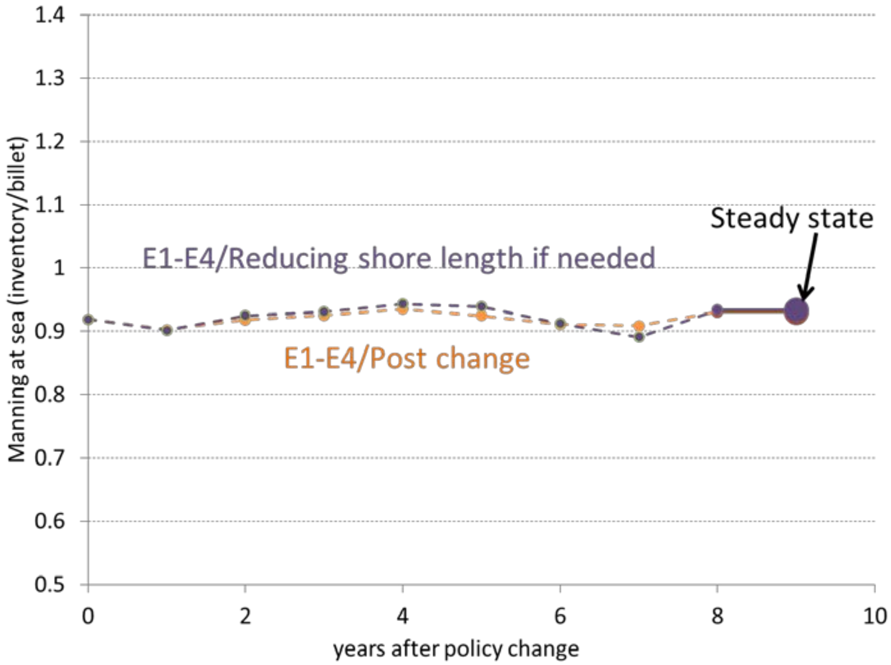


Figure 50. DCs' E5-E6 sea manning under new PST vs. shorter shore length policy

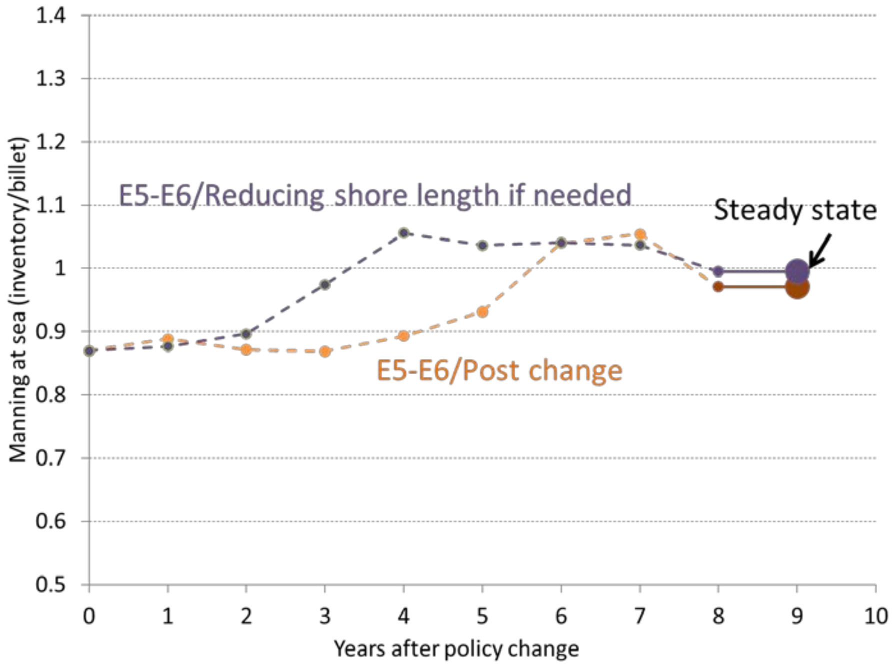
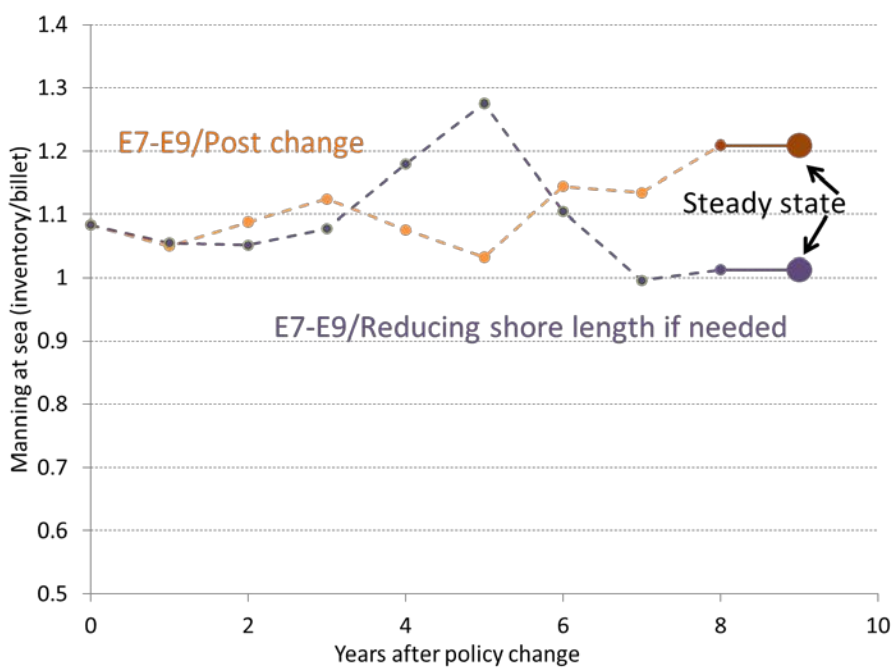


Figure 51. DCs' E7-E9 sea manning under the new PST and shorter shore



Fire Control Technicians (FT)

Figure 52. FTs' E1-E4 sea manning under the new PST and shorter shore

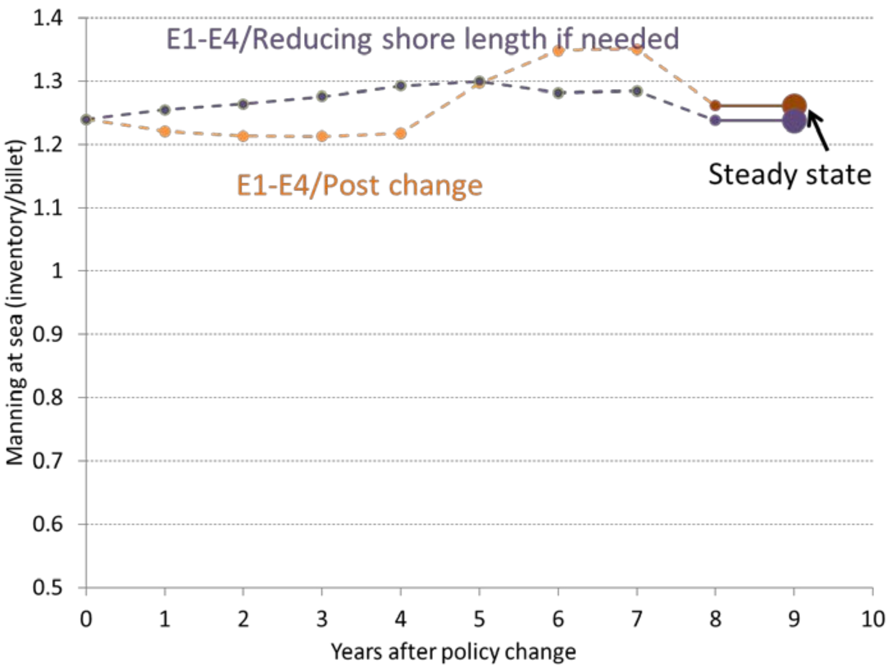


Figure 53. FTs' E5-E6 sea manning under the new PST and shorter shore

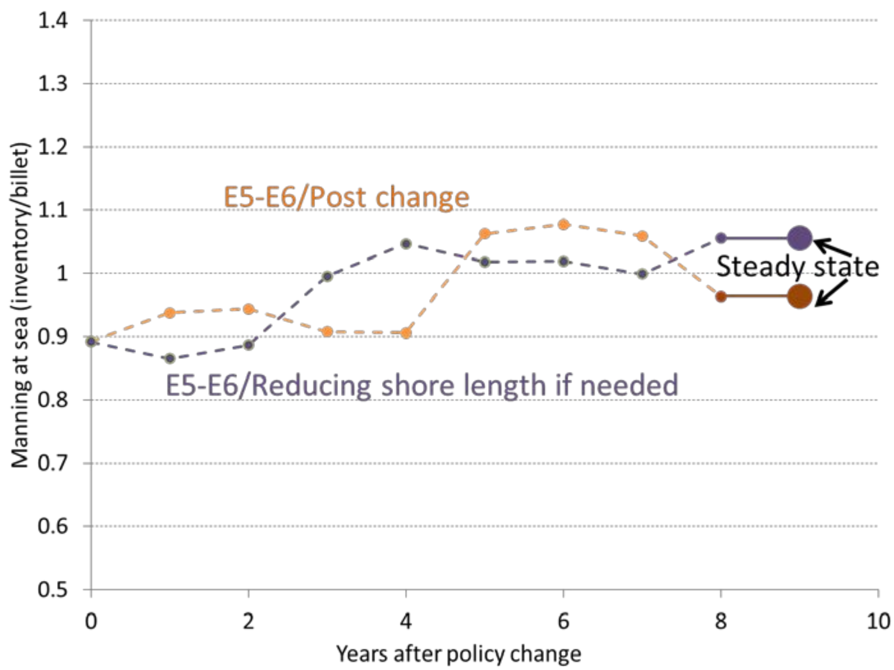
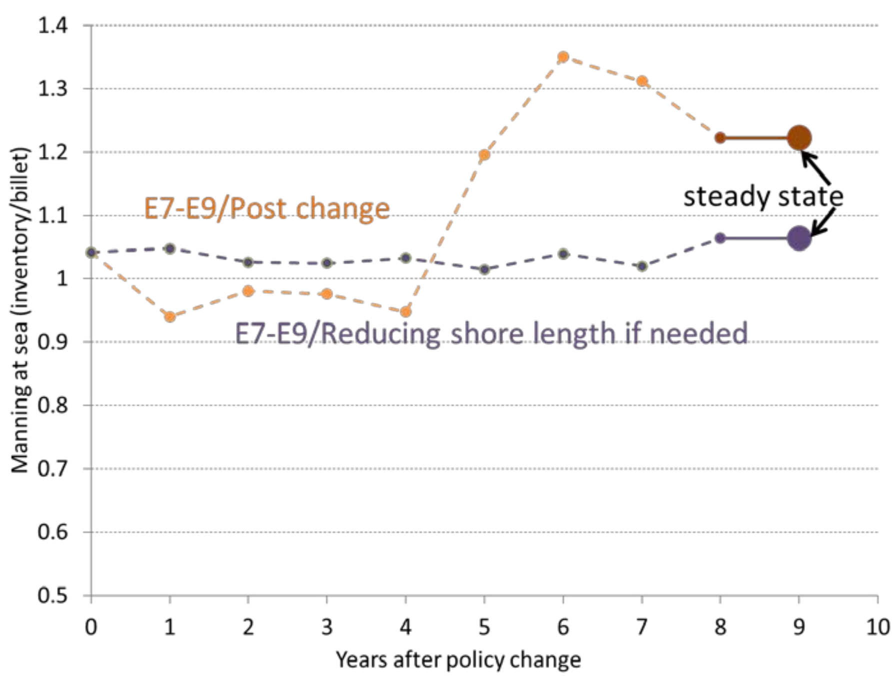


Figure 54. FTs' E7-E9 sea manning under the new PST and shorter shore



Gunner's Mate (GM)

Figure 55. GMs' E1-E4 sea manning under the new PST and shorter shore

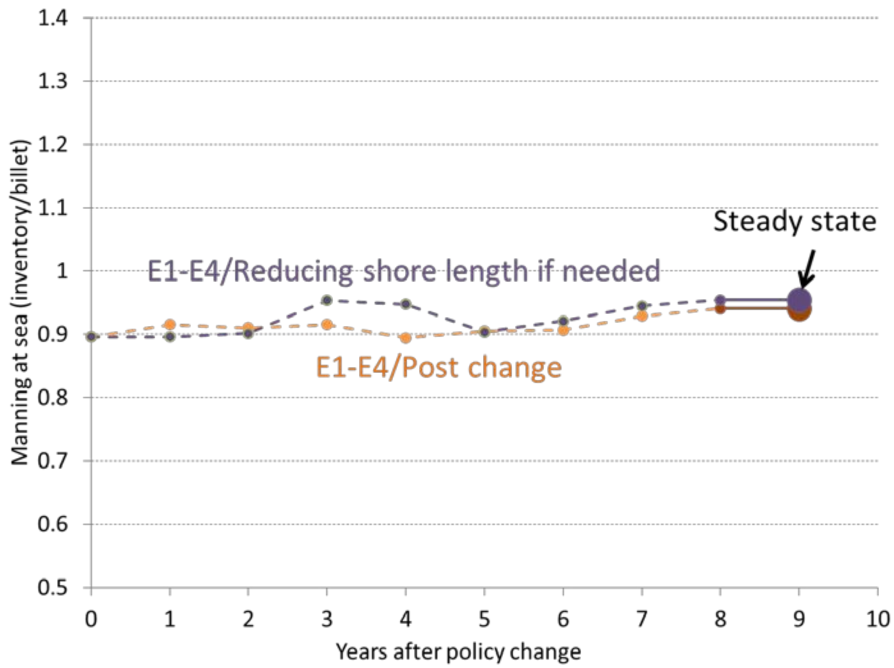


Figure 56. GMs' E5-E6 sea manning under the new PST and shorter shore

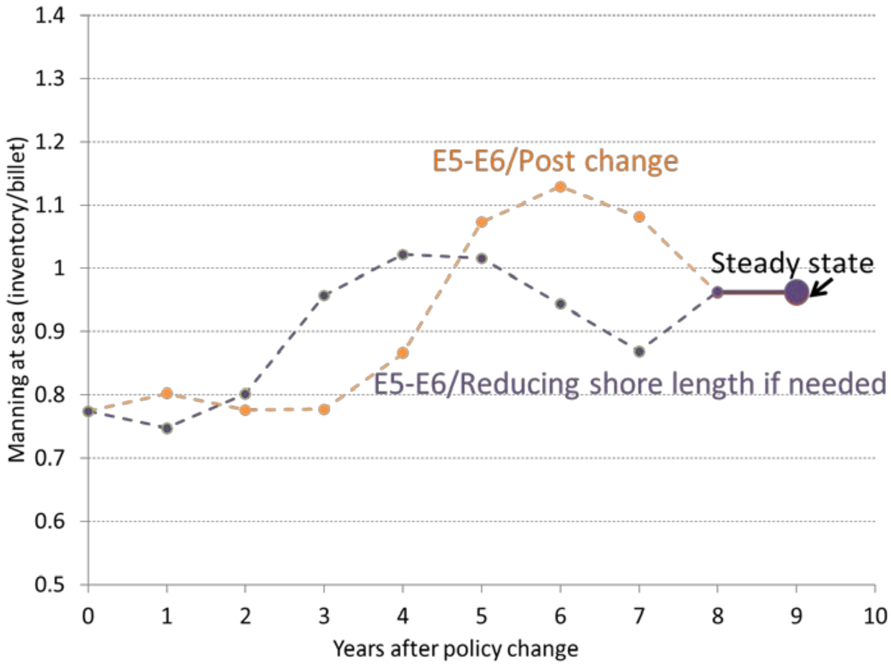
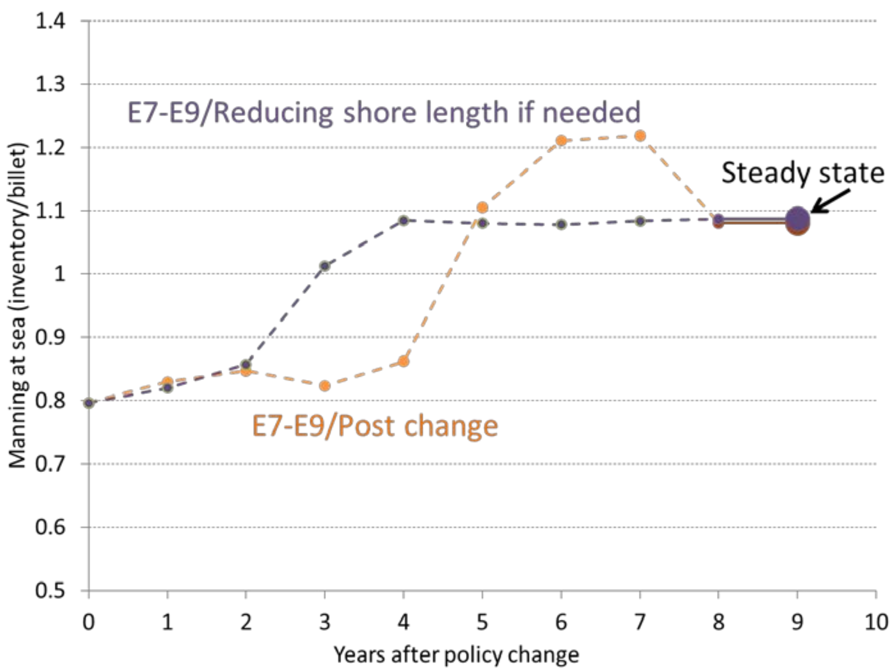


Figure 57. GMs' E7-E9 sea manning under the new PST and shorter shore



Logistics Specialist Submarine (LSSS)

Figure 58. LSSSs' E1-E4 sea manning under the new PST and shorter shore

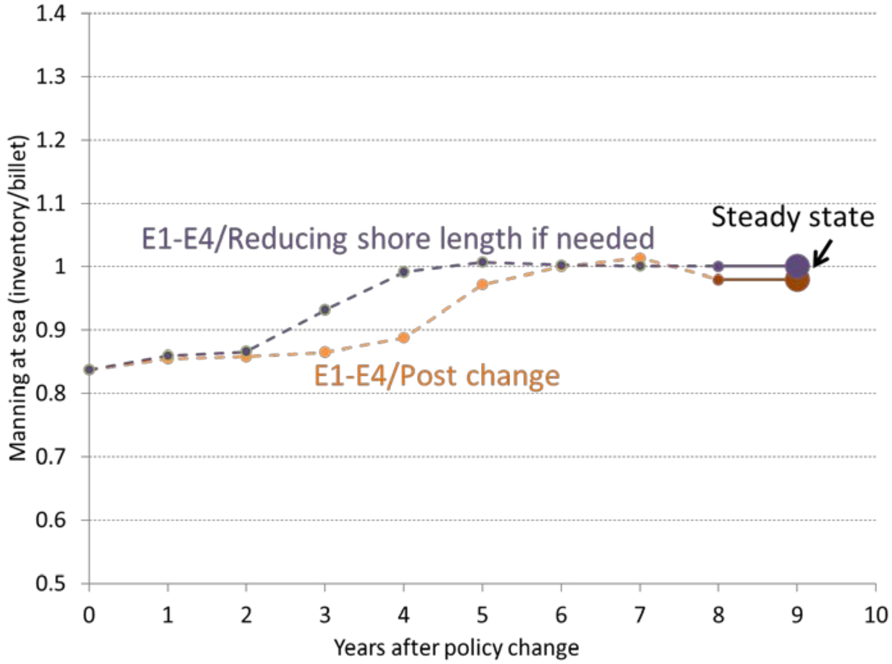


Figure 59. LSSSs' E5-E6 sea manning under the new PST and shorter shore

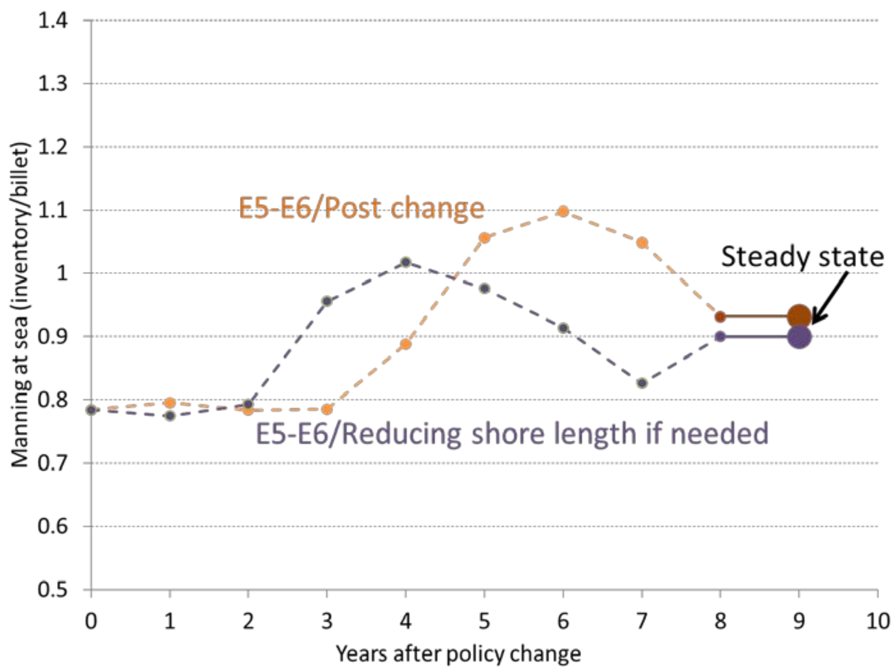
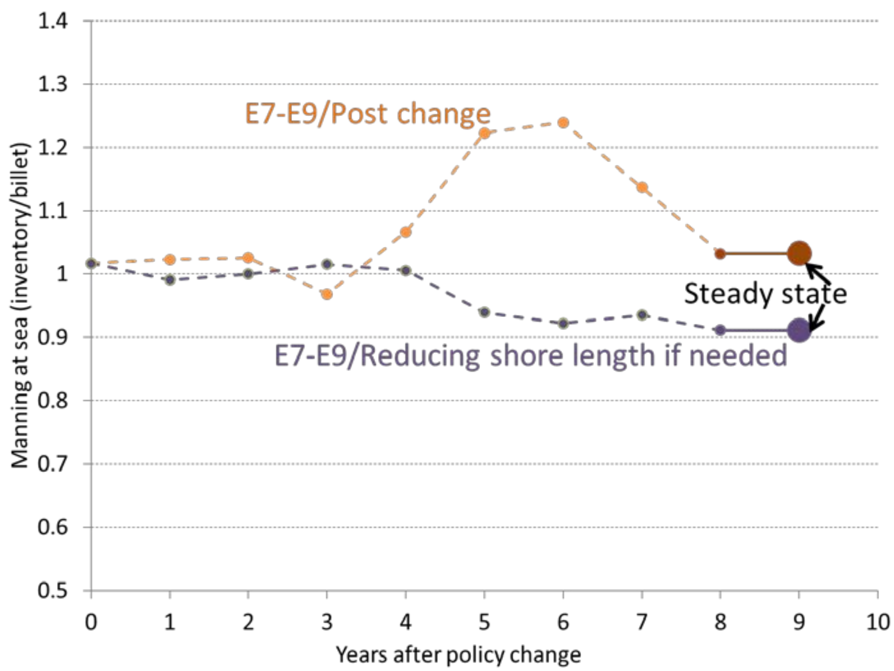


Figure 60. LSSSs' E7-E9 sea manning under the new PST and shorter shore



Machinery Repairmen (MR)

Figure 61. MRs' E1-E4 sea manning under the new PST and shorter shore

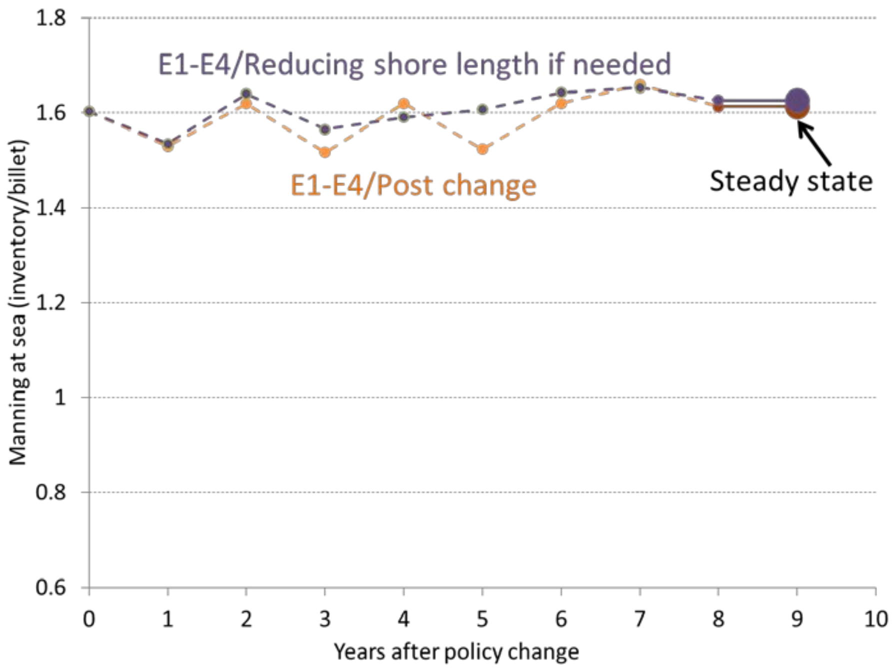


Figure 62. MRs' E5-E6 sea manning under the new PST and shorter shore

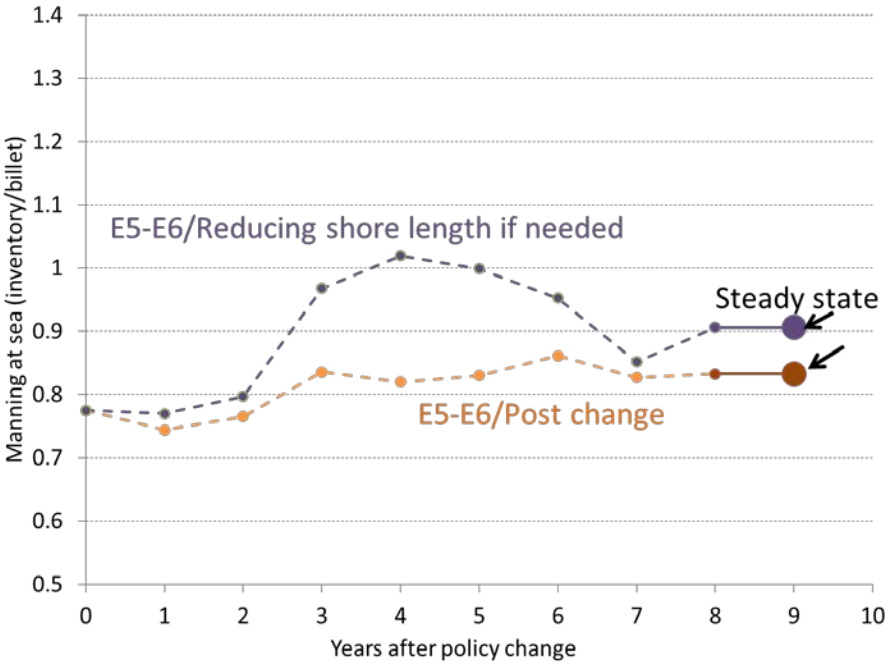
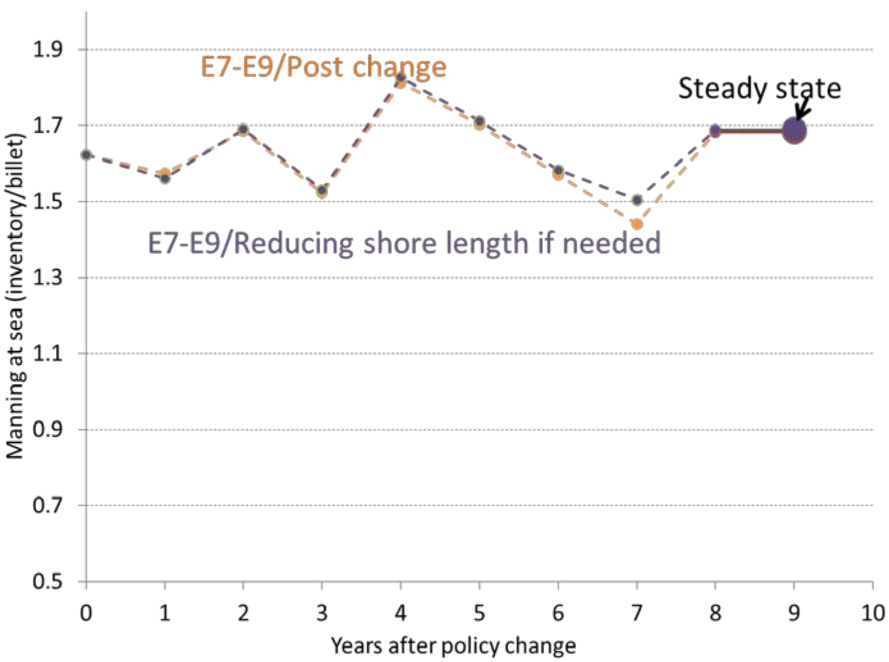


Figure 63. MRs' E7-E9 sea manning under the new PST and shorter shore



Sonar Technician Surface (STG)

Figure 64. STGs' E1-E4 sea manning under the new PST and shorter shore

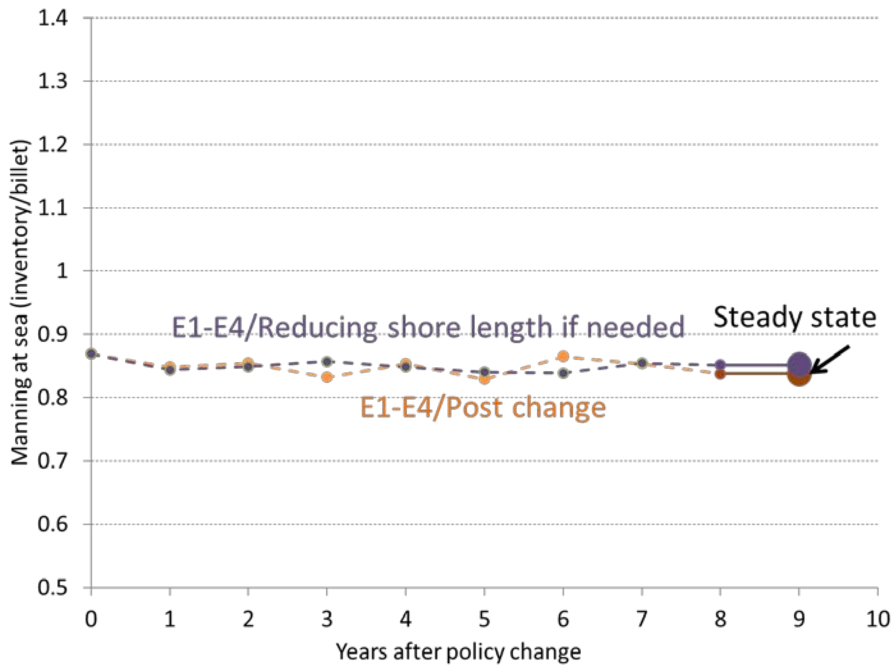


Figure 65. STGs' E5-E6 sea manning under the new PST and shorter shore

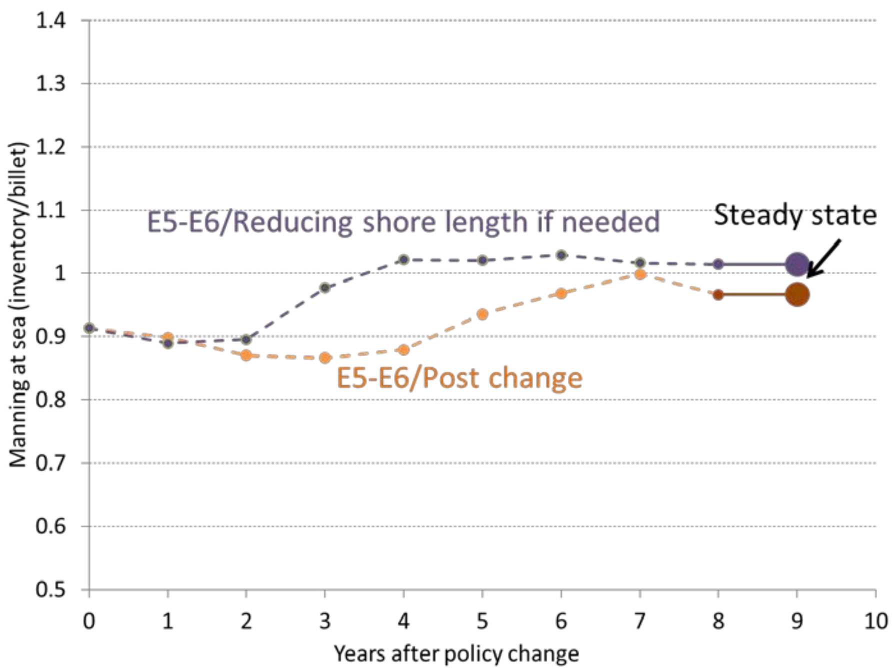
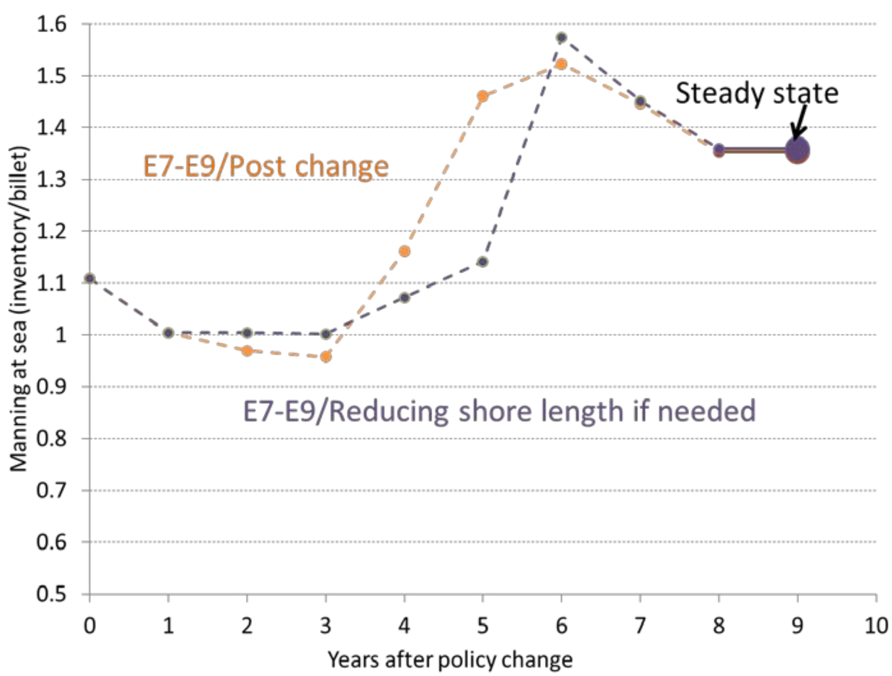


Figure 66. STGs' E7-E9 sea manning under the new PST and shorter shore



Sonar Technician Submarine (STS)

Figure 67. STSs' E1-E4 sea manning under the new PST and shorter shore

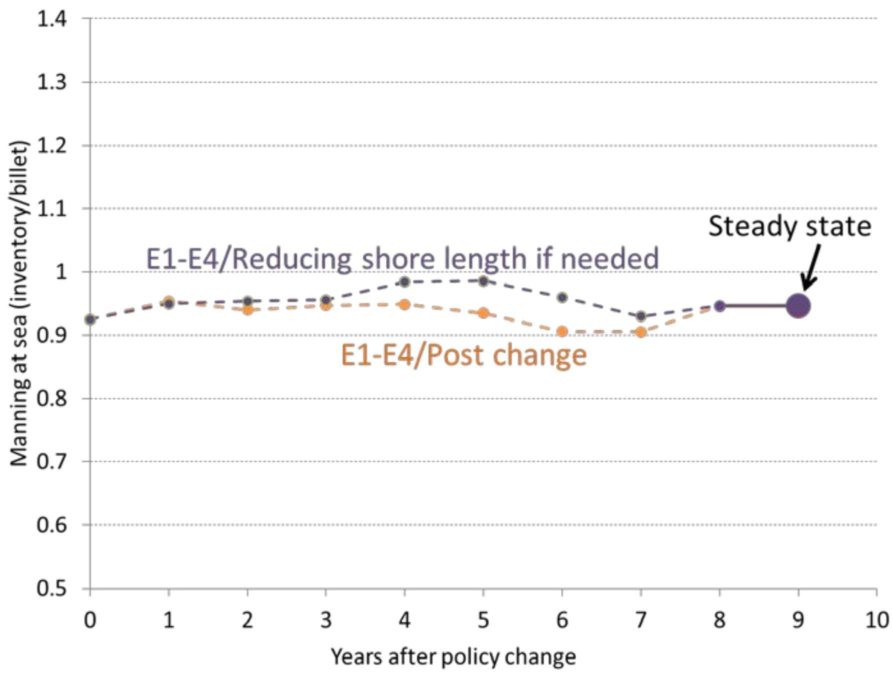


Figure 68. STSs' E5-E6 sea manning under the new PST and shorter shore

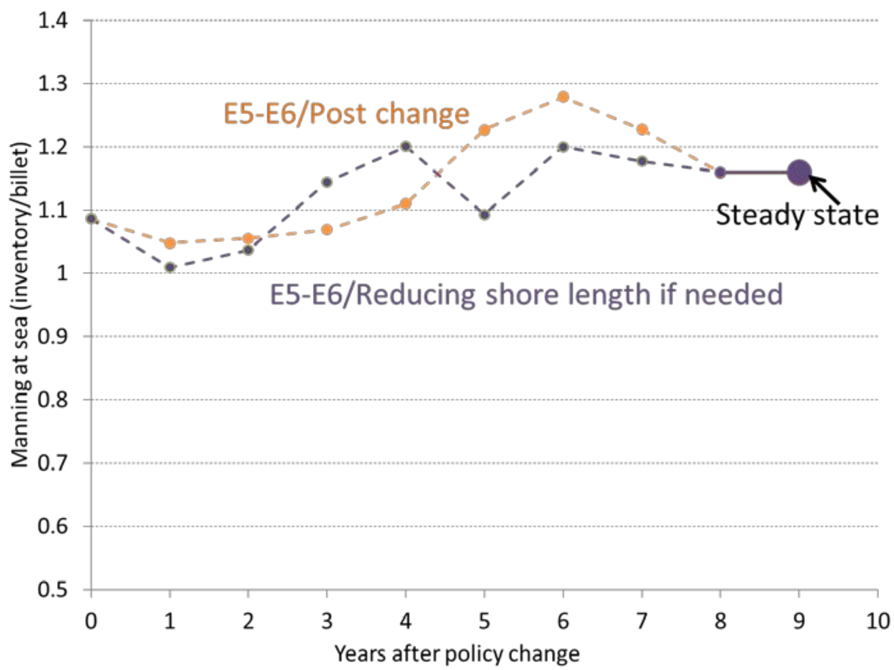
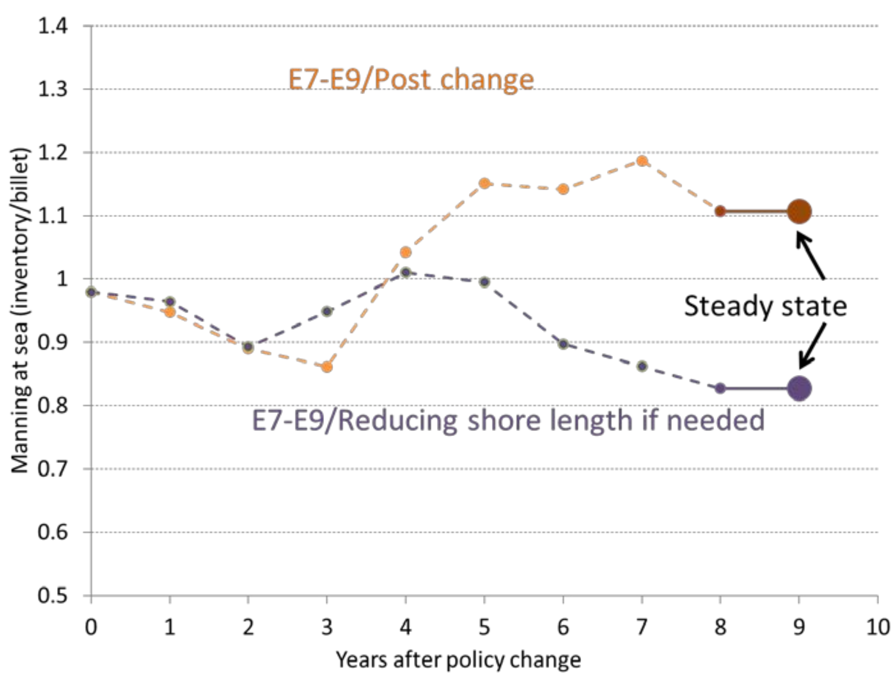


Figure 69. STSs' E7-E9 sea manning under the new PST and shorter shore



Appendix C: Shore Manning

In this appendix, we present the results of the impact of PST change on shore manning. Overall, increased PSTs result in less time at shore, translating to less manning at shore.

Aviation Machinist's Mate (AD)

Figure 70. ADs' E1-E4 shore manning under the old and the new PSTs

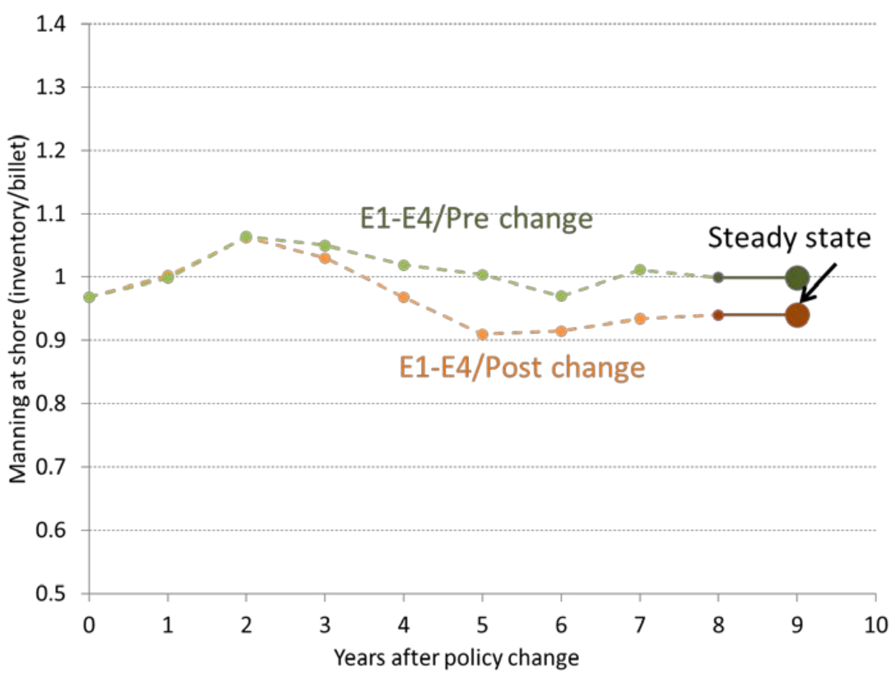


Figure 71. ADs' E5-E6 shore manning under the old and the new PSTs

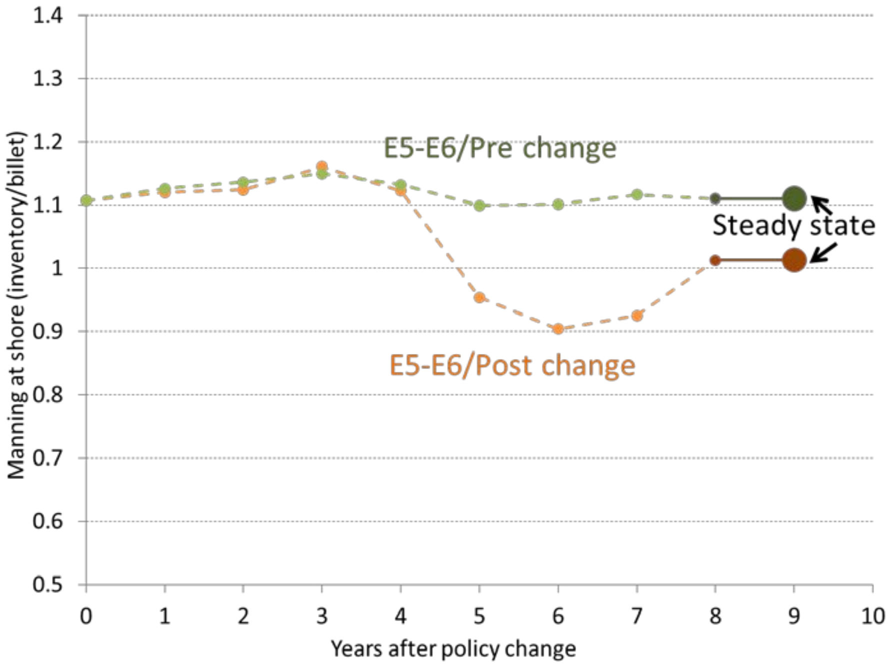
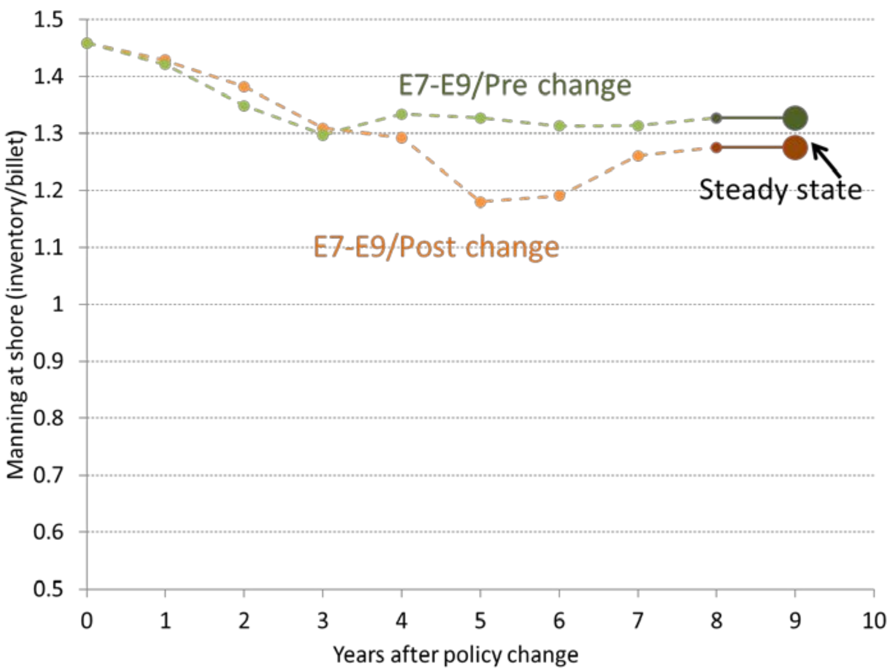


Figure 72. ADs' E7-E9 shore manning under the old and the new PSTs



Culinary Specialist (CS)

Figure 73. CSs' E1-E4 shore manning under the old and the new PSTs

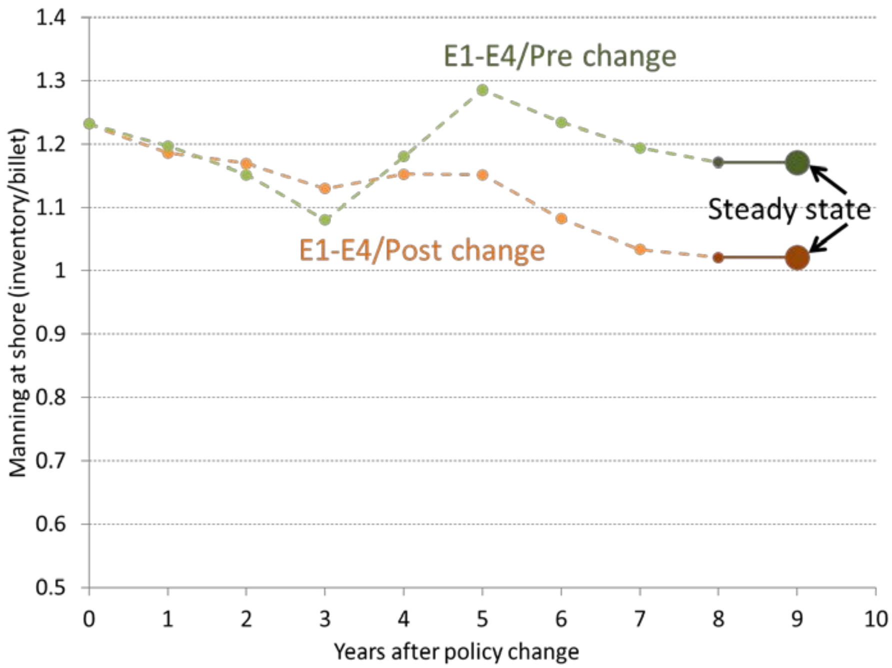


Figure 74. CSs' E5-E6 shore manning under the old and the new PSTs

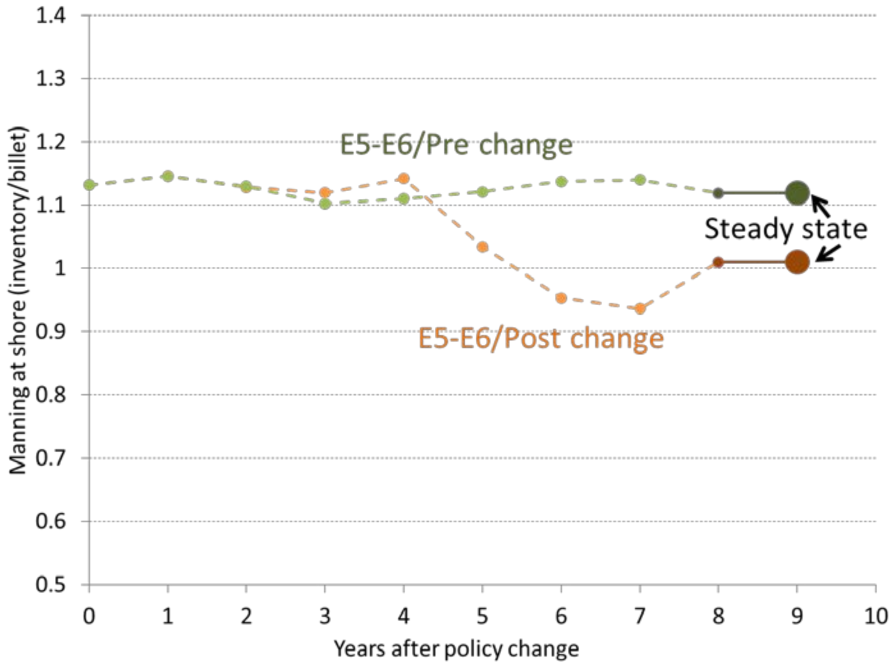
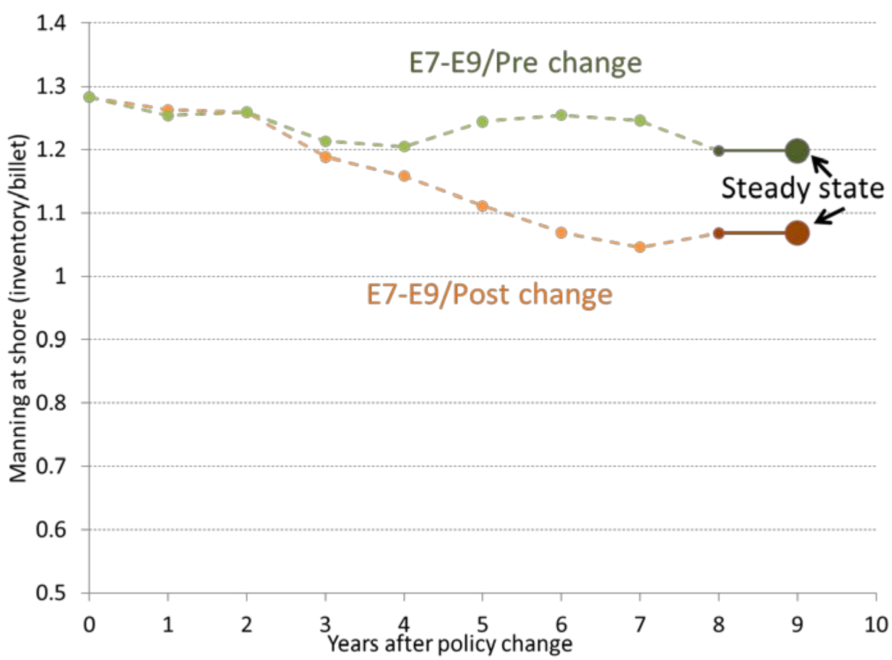


Figure 75. CSs' E7-E9 shore manning under the old and the new PSTs



Damage Control (DC)

Figure 76. DCs' E1-E4 shore manning under the old and the new PSTs

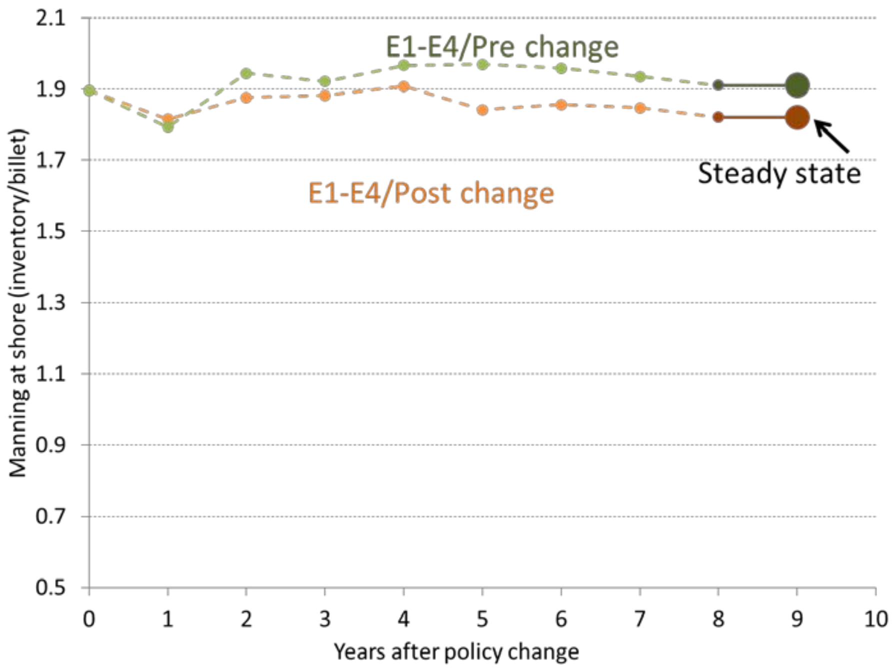


Figure 77. DCs' E5-E6 shore manning under the old and the new PSTs

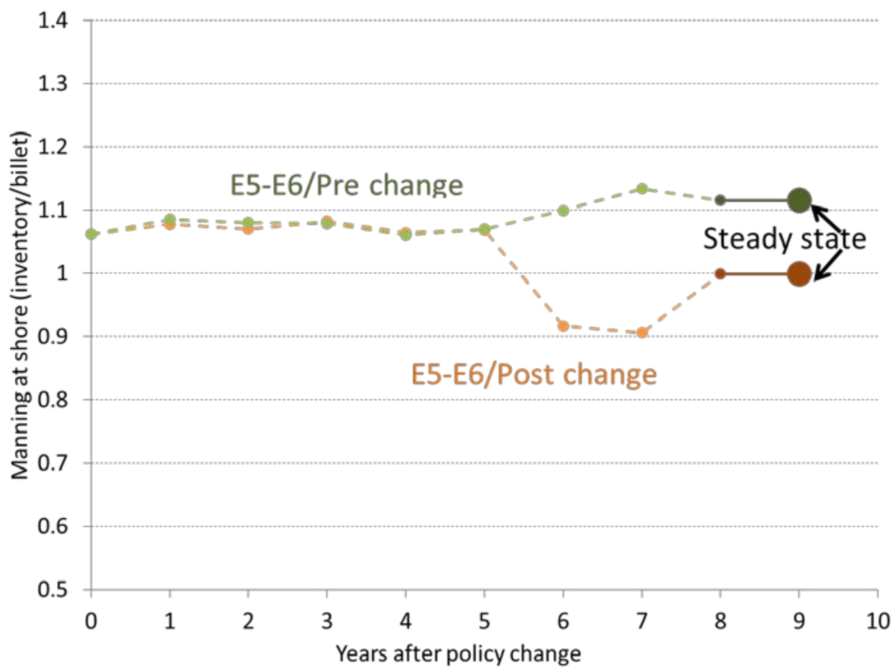
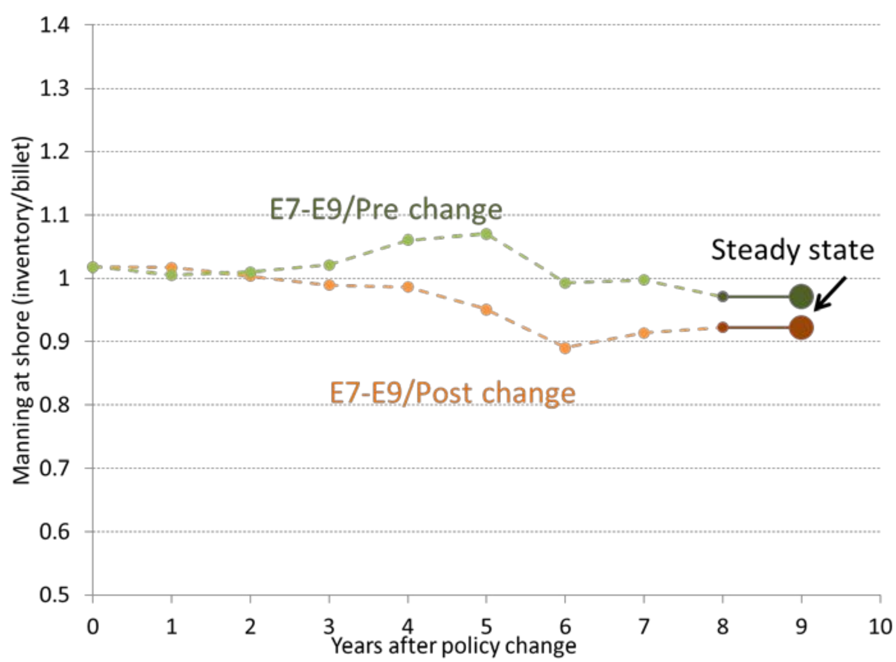


Figure 78. DCs' E7-E9 shore manning under the old and the new PSTs



Fire Control Technician (FT)

Figure 79. FTs' E1-E4 shore manning under the old and the new PSTs

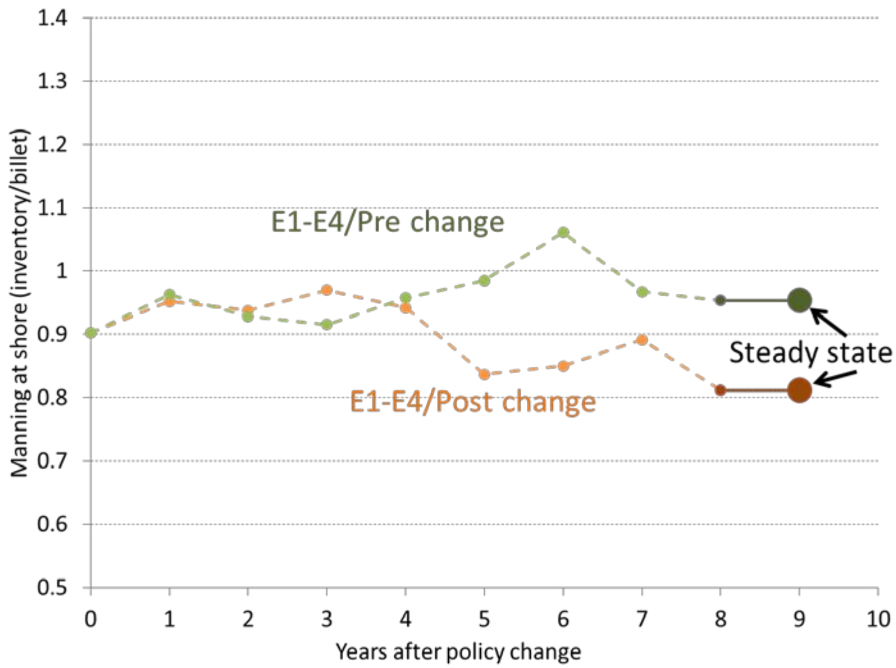


Figure 80. FTs' E5-E6 shore manning under the old and the new PSTs

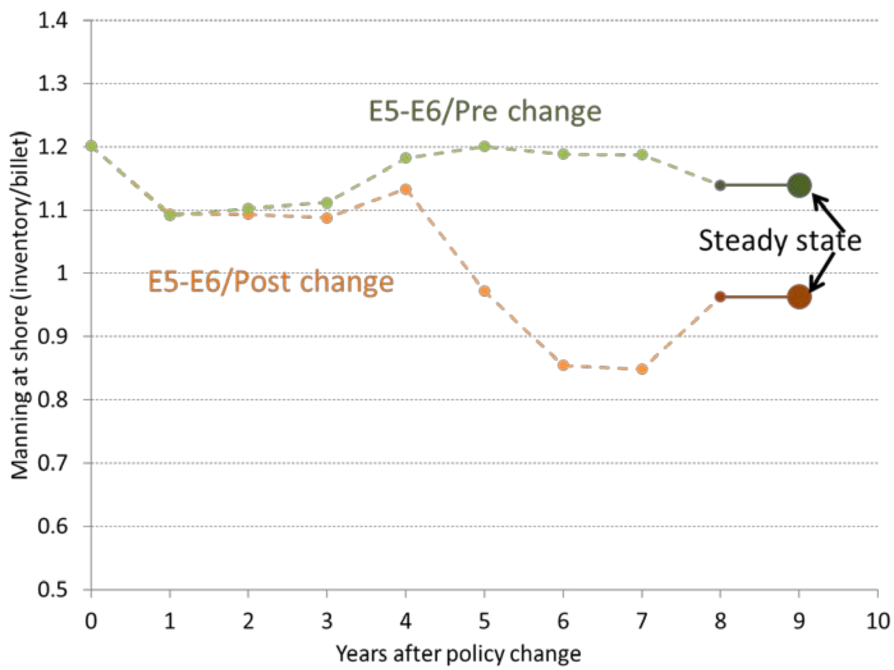
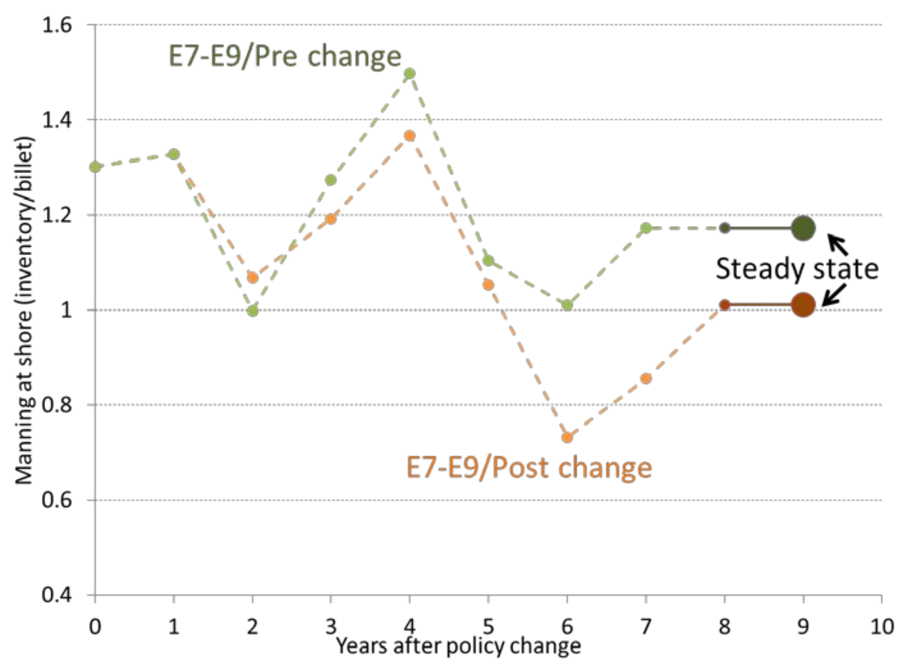


Figure 81. FTs' E7-E9 shore manning under the old and the new PSTs



Gunner's Mate (GM)

Figure 82. GMs' E1-E4 shore manning under the old and the new PSTs

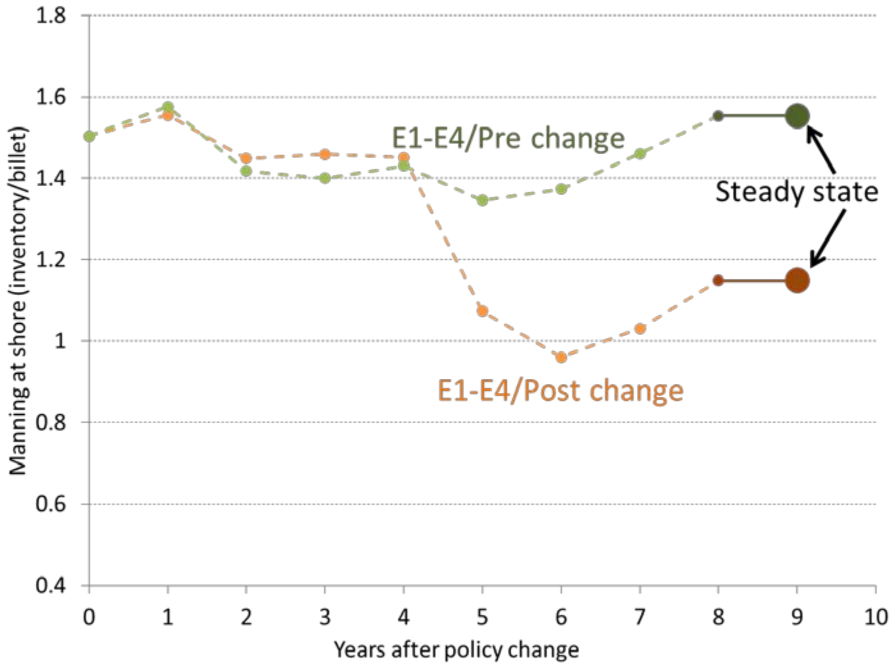


Figure 83. GMs' E5-E6 shore manning under the old and the new PSTs

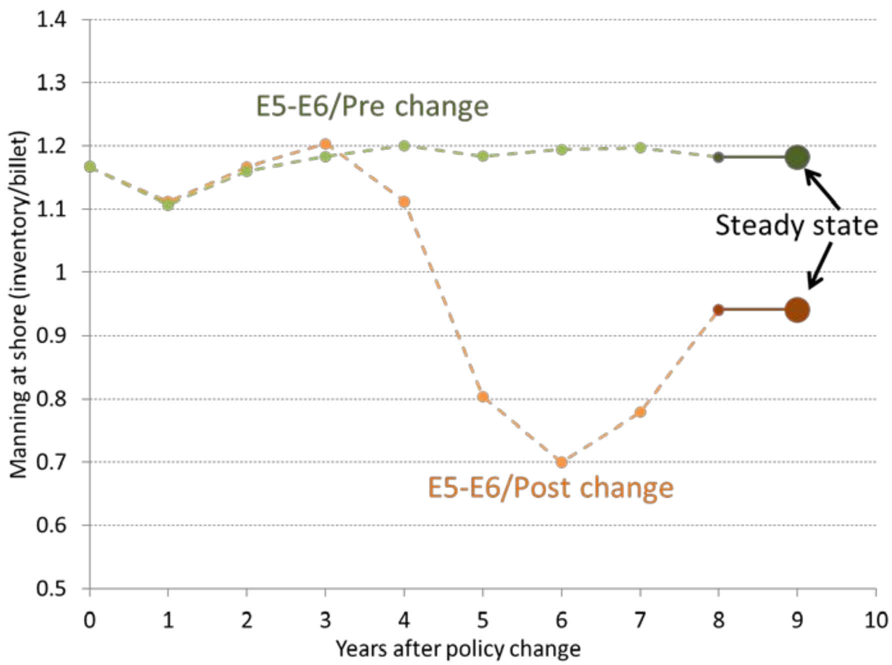
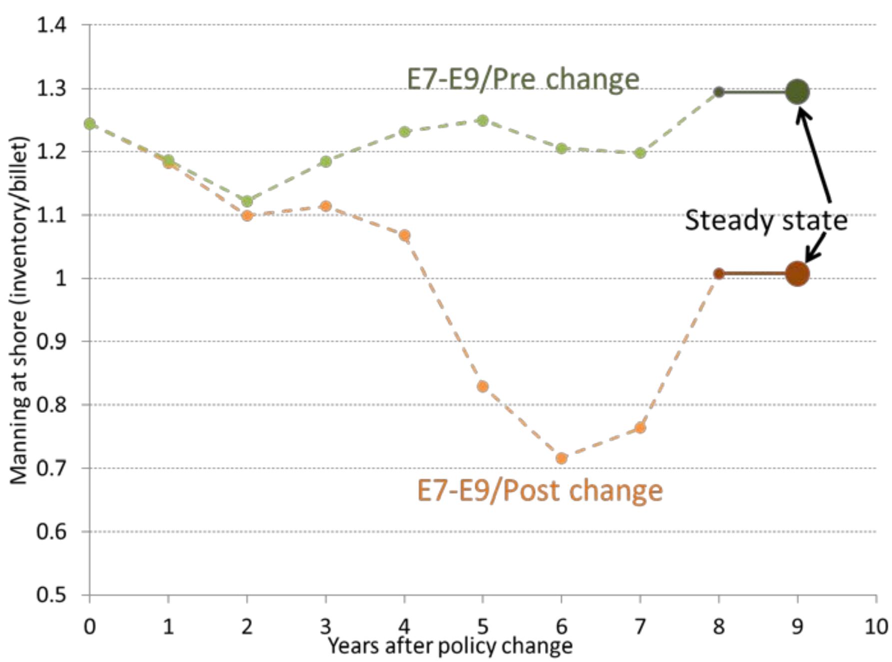


Figure 84. GMs' E7-E9 shore manning under the old and the new PSTs



Logistics Specialist Submarine (LSSS)

Figure 85. LSSSs' E1-E4 shore manning under the old and the new PSTs

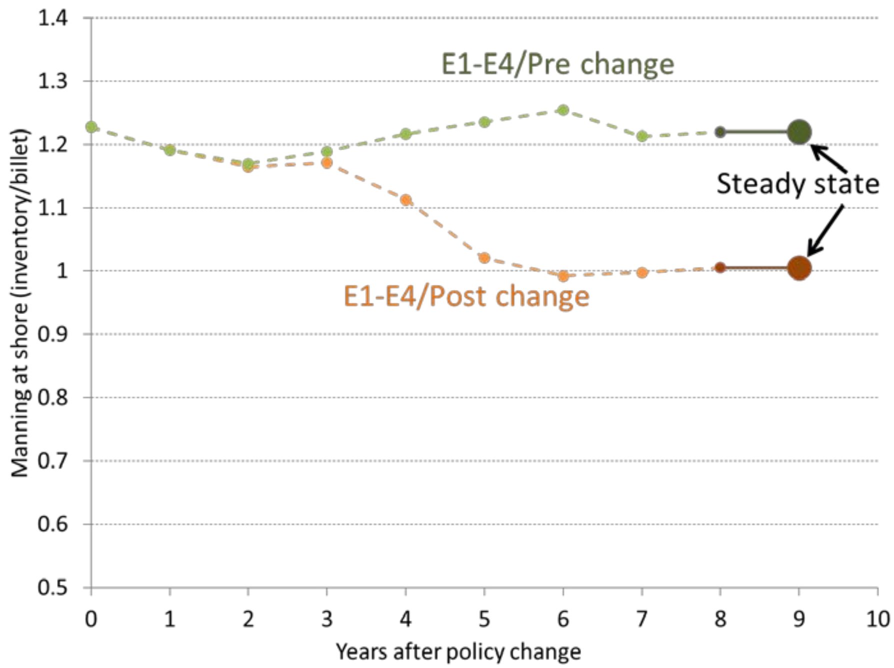


Figure 86. LSSSs' E5-E6 shore manning under the old and the new PSTs

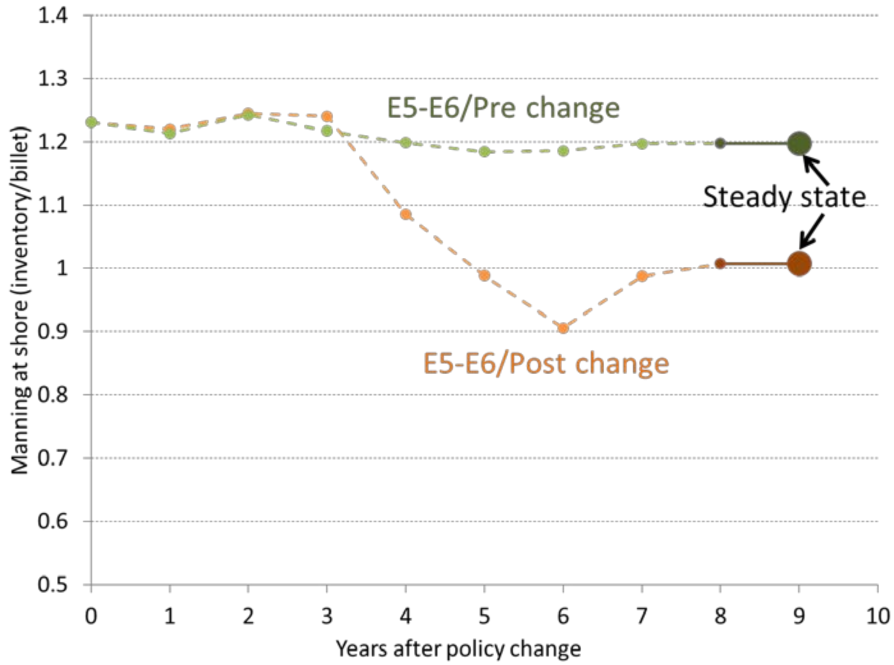
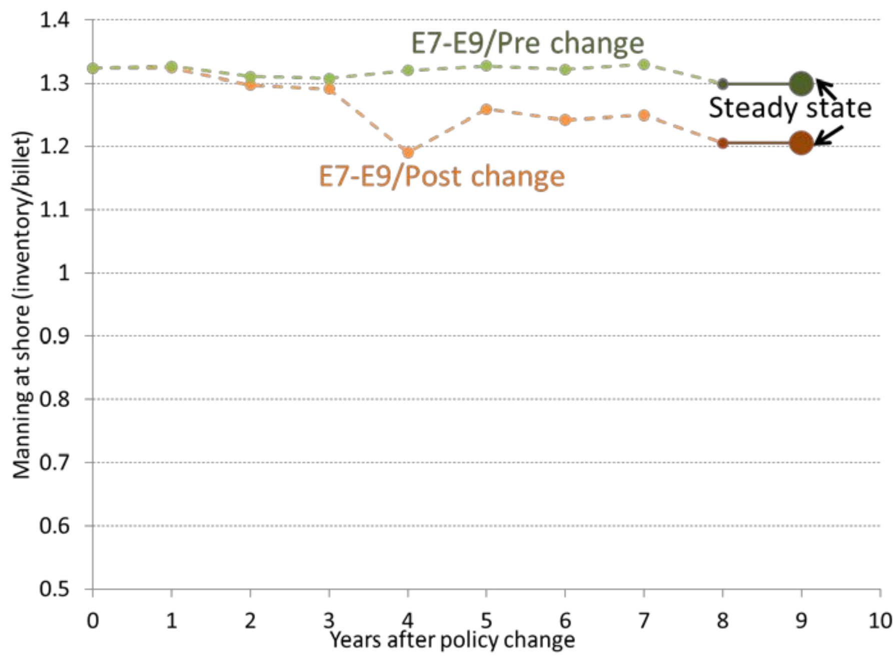


Figure 87. LSSSs' E7-E9 shore manning under the old and the new PSTs



Machinery Repairmen (MR)

Figure 88. MRs' E1-E4 shore manning under the old and the new PSTs

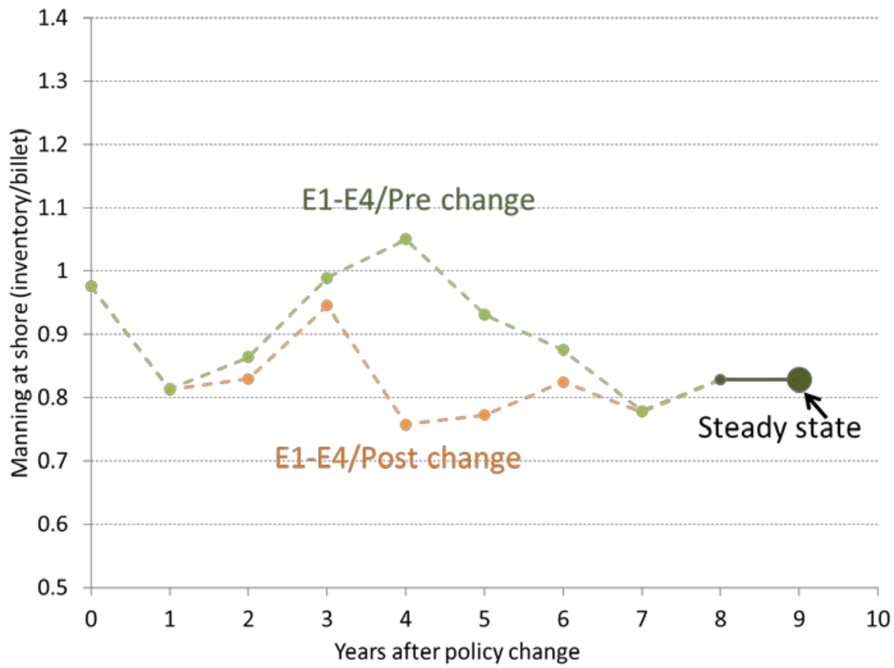


Figure 89. MRs' E5-E6 shore manning under the old and the new PSTs

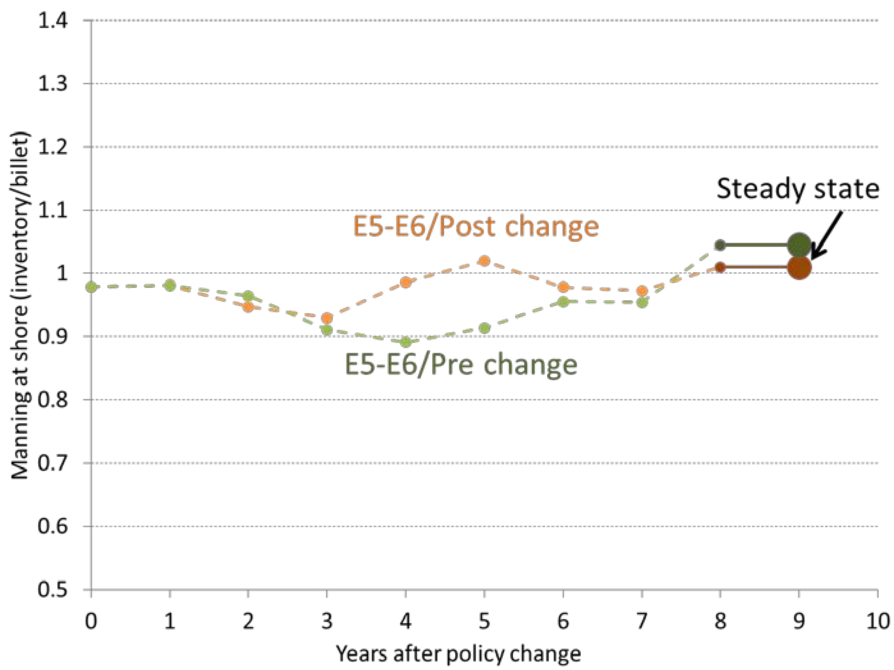
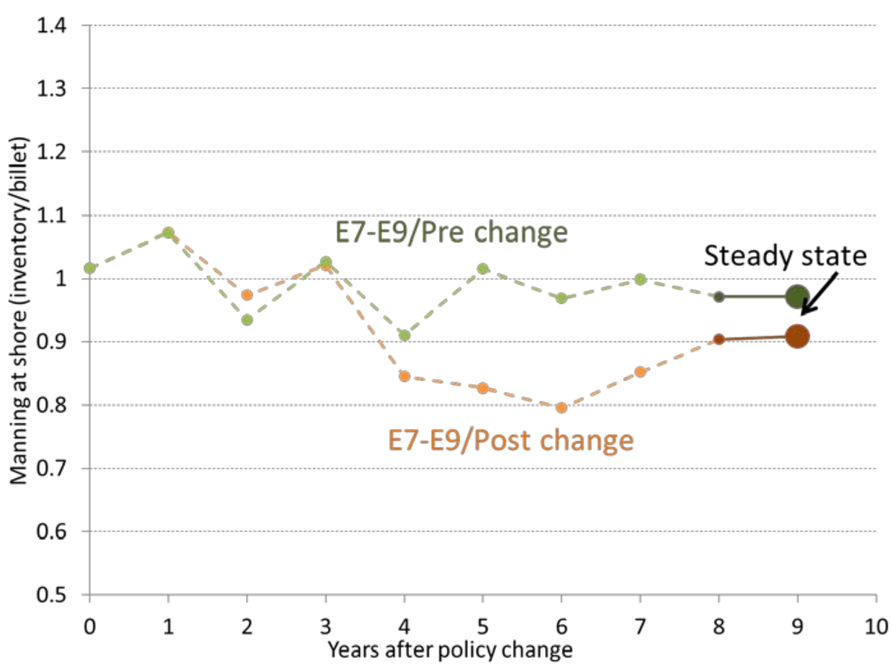


Figure 90. MRs' E7-E9 shore manning under the old and the new PSTs



Sonar Technician Surface (STG)

Figure 91. STGs' E1-E4 shore manning under the old and the new PSTs

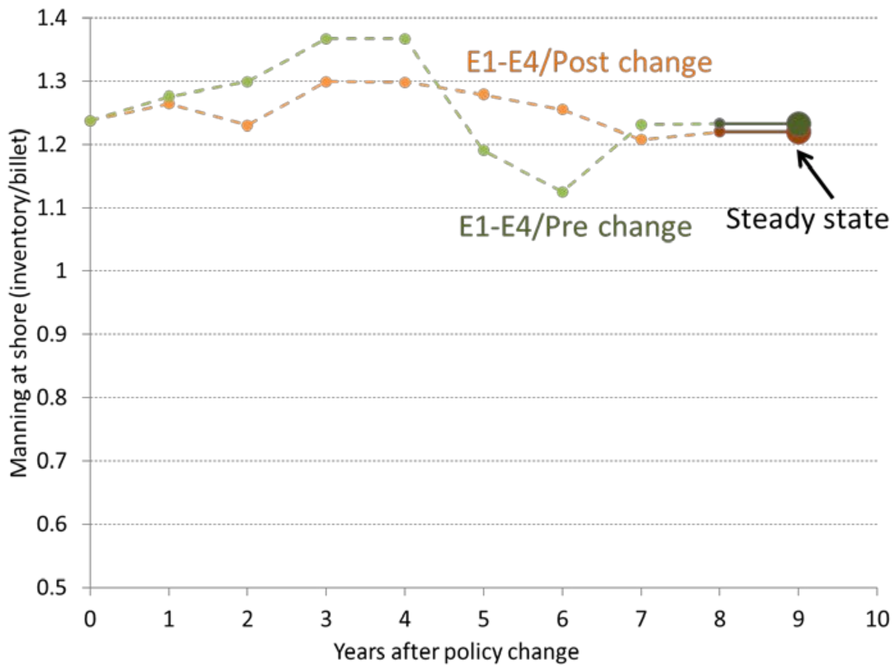


Figure 92. STGs' E5-E6 shore manning under the old and the new PSTs

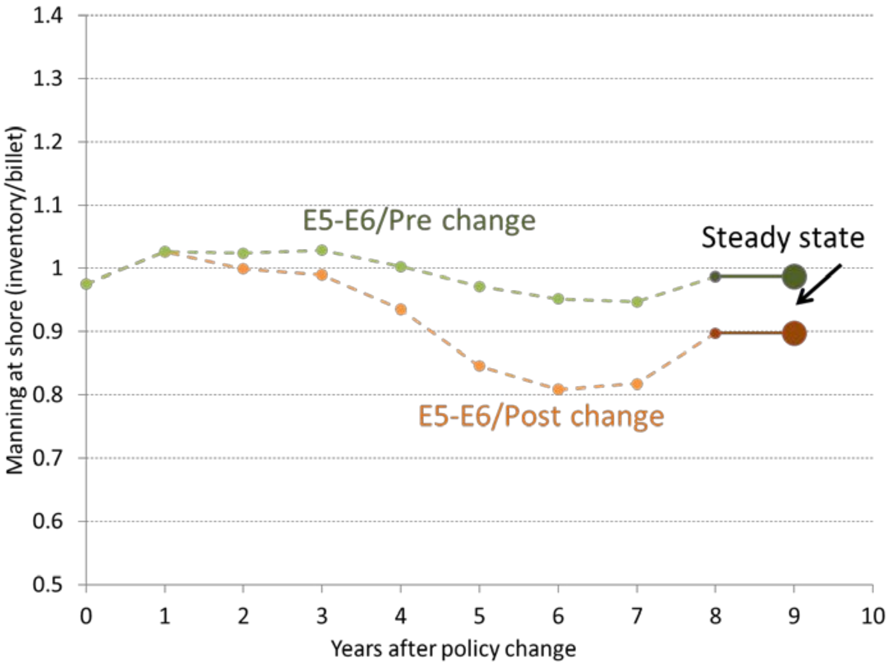
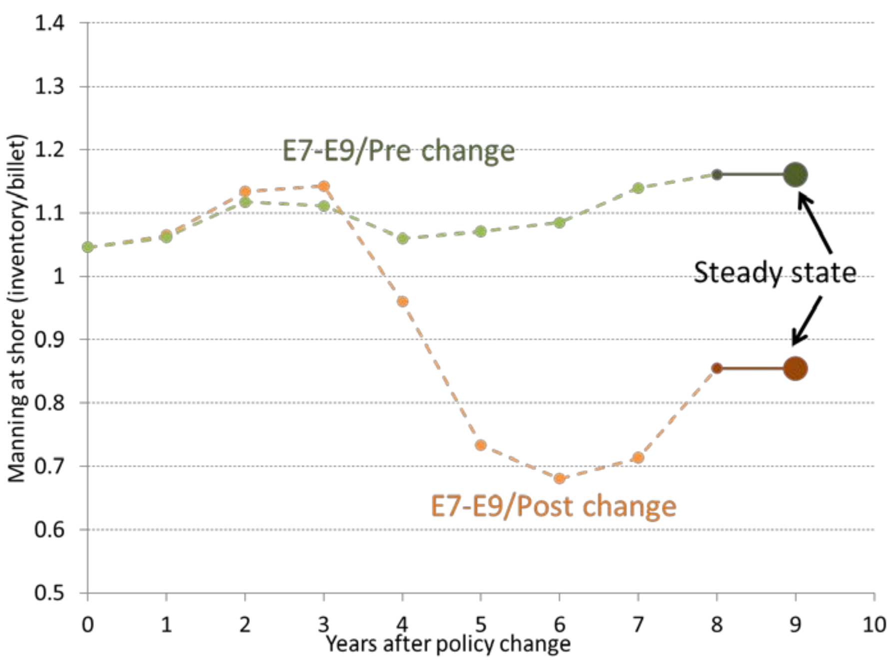


Figure 93. STGs' E7-E9 shore manning under the old and the new PSTs



Sonar Technician Submarine (STS)

Figure 94. STSs' E1-E4 shore manning under the old and the new PSTs

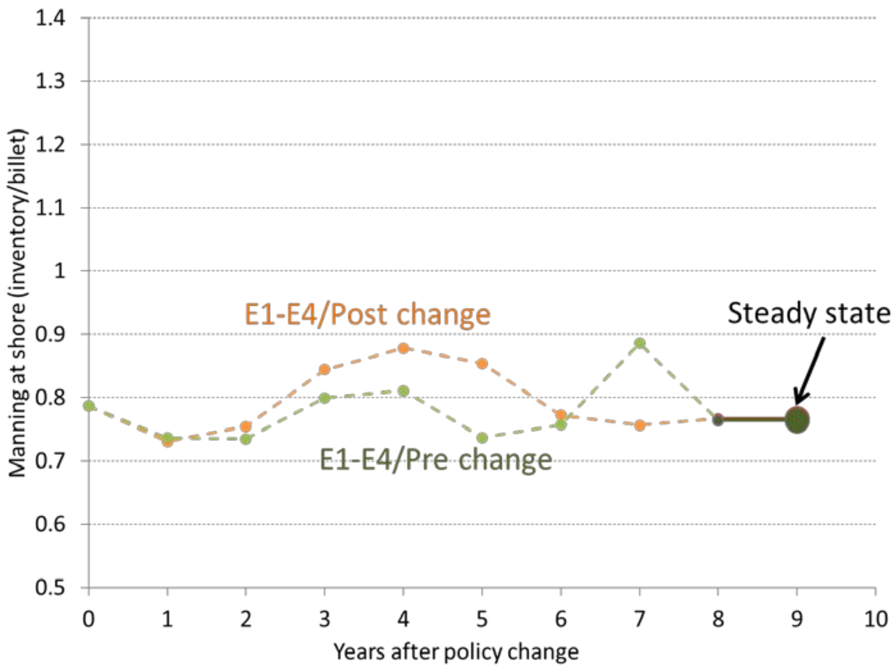


Figure 95. STSs' E5-E6 shore manning under the old and the new PSTs

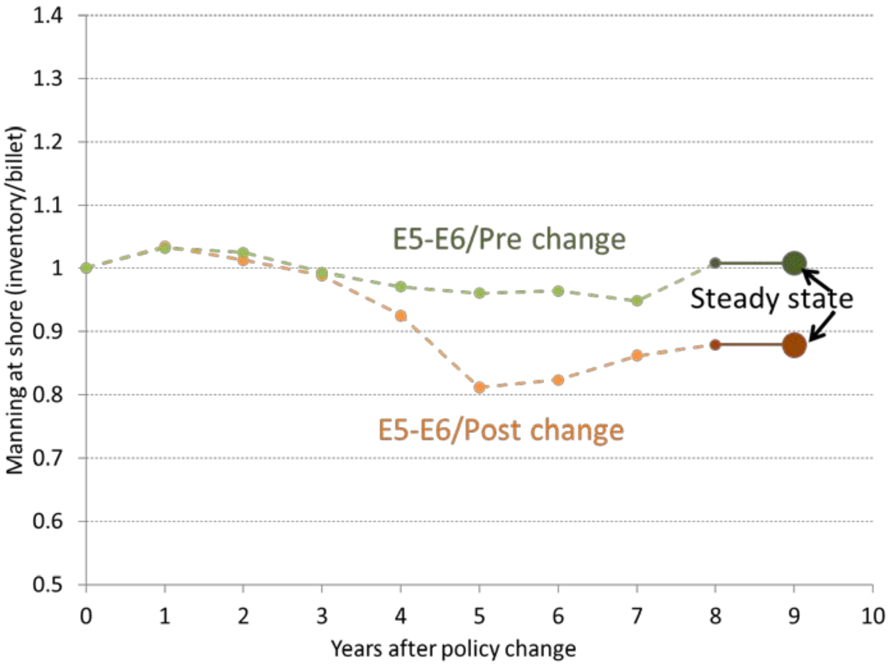
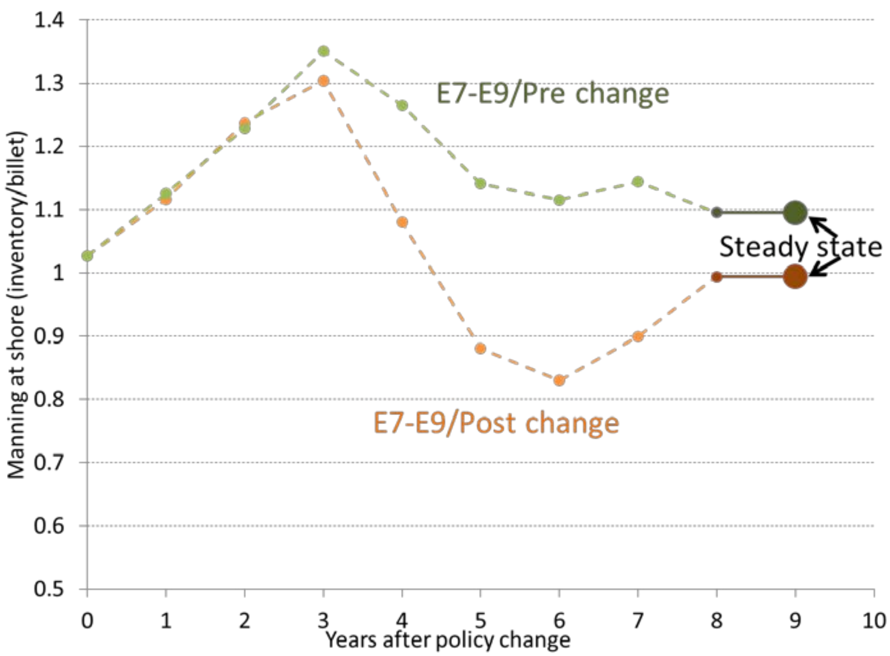


Figure 96. STSs' E7-E9 shore manning under the old and the new PSTs



References

[1] Navy Message, NAVADMIN 234/08. Aug. 2008. *Sea Shore Flow (SSF) Enlisted Career Paths*. Announces the establishment of the Navy's SSSF.

[2] Law, A. M., and D. W. Kelton. 2000. *Simulation Modeling and Analysis*. 3rd ed. New York: McGraw Hill.

[3] McIntosh, Molly F., David Gregory, and Hoda Parvin. 2014. *Manning at Sea: Understanding the Effect of Sea Shore Flow.* CNA. DRM-2014-U-008132-SR1.

[4] NAVY, U.S. 2016. " Enlisted Community Manager Page." Navy Personnel Command. 11 March 2016. http://www.public.navy.mil/bupers-npc/enlisted/communityPages/default.aspx.

[5] Ott, L. 1984. *An Introduction to Statistical Methods and Data Analysis*. 2nd ed. Duxbury, MA: Duxbury Press.

[6] Ramsey, F. L., and D. W. Schafer. 2002. *The Statistical Sleuth: A Course in Methods of Data Analysis*. 2nd ed. Boston: Brooks/Cole.

[7] Ary, D., L. C. Jacobs, and C. Sorensen. 2006. *Introduction to Research in Education*. 8th ed. Belmont, CA: Wadsworth.

[8] Snedecor, G. W., and W. G. Cochran. 1989. *Statistical Methods*. 8th ed. Hoboken: Wiley-Blackwell.

[9] Lin, M., H. C. Lucas, Jr., and G. Shmueli. 2013. “Too Big To Fail: Large Samples and the p-Value Problem.” *Information Systems Research* 24 (4): 906-917.

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